Papeles de Agua Virtual

The water footprint of olive oil in Spain

G. Salmoral
M.M. Aldaya
D. Chico
A. Garrido
M.R. Llamas

Número 7

FUNDACIÓN BOTÍN

PAPELES DE AGUA VIRTUAL

Número 7

THE WATER FOOTPRINT OF OLIVE OIL IN SPAIN

G. Salmoral[1], M.M. Aldaya[1,3], D. Chico[1], A. Garrido[1] and M.R. Llamas[2]

[1] CEIGRAM - Research Centre for the Management of Agricultural and Environmental Risks, Departament of Agricultural Economics, Technical University of Madrid, 28040, Madrid, Spain
[2] Departament of Geodynamics, Geology Faculty, Complutense University of Madrid, 28040, Madrid, Spain
[3] Twente Water Centre, University of Twente, Enschede, The Netherlands

FUNDACIÓN BOTÍN

http://www.fundacionmbotin.org

Papeles de Agua Virtual. Observatorio del Agua
Edita: Fundación Marcelino Botín. Pedrueca, 1 (Santander)
www.fundacionmbotin.org

ISBN: 978-84-96655-23-2 (obra completa)
ISBN: 978-84-96655-79-9 (Número 7)
Depósito legal: M. 51.651-2010
Impreso en REALIGRAF, S.A. Madrid, noviembre de 2010

Table of contents

SUMMARY 5
1. Introduction 7
2. Method and data 9
   2.1. Supply chain water footprint 11
      2.1.1. Supply chain water footprint related to the product ingredients 11
         i) Geo-referenced overlay of crop distribution and type of soil 11
         ii) Green and blue water footprint of olives orchards 13
         iii) Grey water footprint of olive groves 18
      2.1.2. Supply chain water footprint related to other product components 20
   2.2. Operational water footprint 21
   2.3. The water footprint of crop products 23
   2.4 Apparent water productivity of olive oil 25
   2.5. Virtual water exports of olive oil 26
3. Results 26
   3.1. Water footprint of olives orchards 26
   3.2. Water footprint of olive oil 30
   3.3. Apparent water productivity (AWP) of olive oil 33
   3.4. Virtual water exports of olive oil 35
4. Discussion 36
5. Conclusion 41
Acknowledgements 43

References.. 43
Appendix 1: Crop parameters.................................... 51
Appendix 2: Area and crop yield for rainfed and irrigated olive trees for olive oil production................ 52
Appendix 2: Area and crop yield for rainfed and irrigated olive trees for olive table production 56
Appendix 3: The water footprint of olive orchards in m^3/ton for each province over the period 1997-2008. 60
Appendix 4: The water footprint of olive oil in l/l for each province over the period 1997-2008 64
Appendix 5: The apparent water productivity (AWP) in €/m^3 for each province over the period 1997-2008. 68

Summary

The production of olive oil requires substantial volumes of water, which vary depending on the climate conditions, production system and location of the orchards. This paper evaluates spatially and temporally the water footprint of Spanish olives and olive oil over the period 1997-2008. In particular, it analyses the volumetric and economic green, blue and grey water footprints of olive oil in Spain and the related virtual water exports.

In line with previous studies which look at the water footprint of agriculture based products, most of the supply chain water footprint per litre of olive oil is coming from its ingredients (>99.5%), that is, the olive production, whereas a smaller fraction comes from the other components (<0.5%), mainly from the plastic based bottle, cap and label. The water footprint per unit of a product allows to estimating the efficiency of production in relation to water consumption and pollution. Over the studied period the green water footprint in m^3 plays an important role in the Spanish olive oil production, representing about 71% in rainfed systems versus 12% in irrigated. Blue and grey water footprints comprise 7% and 10% of the national water footprint respectively. The increase of blue groundwater consumption from 106 to 378 million m^3 in the main olives producing region (Andalusia) between 1997 and 2008 indicates the pressure that water resources may be facing. Apparent water productivities are lower and more sensitive to variations in rainfed systems than in irrigated ones. Finally, the virtual water exports through olive oil exports also illustrate the importance of green water foot-

print amounting to about 77% of the total virtual water exports.

The spatial and temporal variability of the water footprint per unit of olives and olive oil does not make possible to determine a fixed value. Most relevant water management improvements for olive oil production can be achieved at the olive growing stage in the field.

1. Introduction

In a context where water resources are unevenly distributed and, in regions where flood and drought risks are increasing, enhanced water management in Spain is a major challenge not only to water users and managers but also to final consumers, businesses and policymakers in general. In this country, about 85% of all water is used to grow food (Garrido et al., 2010). Spain is the first world producer and exporter of olive oil and table olives. Combining rainfed and irrigated area, olive production is the second crop in extension at national level after cereals (OOA, 2010a) with 2 032 290 ha and 418 157 ha of rainfed and irrigated orchards, respectively in 2008 (MARM, 2010a). In 2007/2008 agricultural season, 43% of the estimated olive oil world production was produced in Spain with 1.2 million tonnes, which comprise a gross production of 1,990 million euro (MARM, 2010a; 2010b).

The water footprint of a product is the volume of freshwater used to produce the product, measured over the full supply chain. It is a multidimensional indicator, showing water consumption volumes by source and polluted volumes by type of pollution (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. 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 as the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards. Previous to this study, Garrido et al.

(2010) calculated a total water footprint for crop production (blue and green) in Spain of 27,620 and 23,590 million m^3 for a humid (1997) and dry (2005) year type, respectively. The green and blue water footprint of olives represented 35% of the total water footprint of crop production in Spain for the period 1997-2006.

Authors have stated that drought events can be mitigated and water savings achieved through global virtual trade in water stress regions (Allan 1999; Chapagain et al., 2006; Hoekstra and Chapagain, 2008), being the unequal spatial distribution of global water resources compensated by virtual water trading (Islam et al., 2007). Other authors indicate that virtual water trade is misleading concept, which cannot be used to alleviate water scarcity (Ansink, 2010) and does not provide alone policy relevant criterion (Wichelns, 2010).

Garrido et al. (2010) affirm that Spain is a net exporter of virtual water embedded in crops, where Andalusia stands out as the largest and most unstable exporter owing mostly to olive oil production. Spain exports high value crops (e.g. vegetables and fruits) and imports lower value crops (e.g. grain) (*ibid*; Novo et al., 2008). Within their study, Garrido et al. (2010) also show that virtual water imports and exports had grown significantly during the period 1997-2006. Most of the exports originate in the Southern and Southeast Regions, which include the most water-stressed basins. Dietzenbacher and Velázquez (2007) also evaluated virtual water trade in Andalusia; being a net virtual water exporter and a semi arid region, questions are raised about the expansion of the olive sector in the region. However, to assess the sustainability of the sector's growth, a detailed geographical and temporal analysis of the three footprint components is required together with a broader evaluation of water use and availability in the basin.

The present study analyses geographically the explicit green, blue and grey water footprints of olives and olive oil, and the apparent water productivities and the related virtual water exports of olive oil over the period 1997-2008 in Spain.

2. Method and data

The green, blue and grey water footprint of olives and olive oil are calculated following and refining the method described by Hoekstra et al. (2009). The water footprint is determined for a region (i.e. province and country) in terms of million m^3 and per unit of product produced in litres/product. First, the water footprint of olive orchards is calculated as a whole (including both oil and table varieties). Two types of olive production systems are analysed: irrigated vs. rainfed. Then, the analysis focuses on the production chain for 1 litre of olive oil, indicating the relevant water consumptive process steps from the source to the final product. Apparent water productivities and virtual water exports calculations are based on Garrido et al. (2010).

The water footprint of olive oil is studied as the water footprint of a product and includes both a supply chain and an operational water footprint.

$$WF_{product} = WF_{supply\ chain} + WF_{operational} \quad [1]$$

Where:

$WF_{product}$: the water footprint of a product (million m^3 or litres/product).

$WF_{supply\ chain}$: the water footprint of the supply chain (million m^3 or litres/product).

$WF_{operational}$: the operational water footprint (million m^3 or litres/product).

The overhead water footprint is the water footprint related to general activities, goods and services needed for running a business such as the water consumption of toilets or the water footprint from construction materials. Compared to the total supply chain and operational water footprint, the overhead water footprint of agriculture based products is almost negligible (Ercin *et al.*, 2009). Thus, both the overhead water footprint for the supply chain and operational water footprints of the olive oil production are excluded from this study.

The water footprint also distinguishes three components: the green, blue and grey water footprint.

$$WF = WF_{green} + WF_{blue} + WF_{grey} \quad [2]$$

Where:

WF: the water footprint (million m^3 or litres/product).

WF_{green}: the green water footprint (million m^3 or litres/-product).

WF_{blue}: the blue water footprint (million m^3 or litres/product).

WF_{grey}: the grey water footprint (million m^3 or litres/product).

The green and blue water footprints per unit indicate the efficiency of water consumption of a crop in terms of rainfall or irrigation water, because both terms show the volume of water consumed per unit of product produced. The grey water footprint per unit can be used as an indicator of potential water pollution.

2.1. Supply chain water footprint

The supply chain water footprint is defined as the amount of freshwater used to produce all the goods and services that form the product inputs at a specific business unit.

$$WF_{supply\ chain} = WF_{supply\ chain\ [ingredients]} + WF_{supply\ chain\ [other\ parts]} \quad [3]$$

The $WF_{supply\ chain}$ (million m^3 or litres/product) comprises the $WF_{supply\ chain\ [ingredients]}$ that refers the water footprint directly associated to ingredients (e.g. olives) and the $WF_{supply\ chain\ [other\ parts]}$ that includes the water footprint of other components (e.g. bottle, cap, labelling materials and packing materials).

2.1.1. Supply chain water footprint related to the product ingredients

The water footprint of olives in Spain has been calculated distinguishing the green, blue and grey water components. The green and blue water evapotranspiration has been estimated using the CROPWAT model (FAO, 2009). This section is used to calculate the water footprint of olives for olive oil and table production.

i) Georeferenced overlay of crop distribution and type of soil

The crop distribution was overlaid with the soil textural classes using ArcGIS 9.3 software. This way, the crop area on each soil textural type was obtained for each of the provinces. The olive orchard cropping pattern is outlined using the Corine Land Cover 2000 (CLC2000) (EEA, 2009) and the Inventory and Characterisation of Irrigated Land in Andalusia 2002 (Regional Government of Andalusia, 2003) (Figure 1). The first layer presents a 1:100,000 scale (EEA, 2000) and the latter is obtained at 1:50,000 scale. CLC2000 illustrates the rainfed and irrigated olive orchards distribution for all provinces, except for the distribution of irrigated olive groves in Andalusia, which is taken from the Inventory. Both layers provide a reliable distribution of this perennial crop and indicate the most probable locations where olive orchards are grown. Nevertheless, both the CLC2000 and the Inventory and Characterisation of Irrigated Land in Andalusia 2002 present some limitations as they have not been updated since their creation. In addition, CLC2000 does not include the six provinces where olive groves have been developed after the year 2000 (Álava,

FIGURE 1. *Olive orchards distribution in Spain and irrigated olive orchards distribution in Andalusia.*

Source: Own elaboration based on EEA (2009) and Regional Government of Andalusia (2003).

Guipúzcoa, Lugo, Las Palmas, Santa Cruz de Tenerife and Valladolid), but these provinces comprised only 852 ha in 2008 out of 2,450,447 ha in Spain as a whole (MARM, 2010a).

Soil type data have been taken from European Soil Data Base version V2.0 at 1,000,000 scale (European Commission), with the exception of Canary Islands, which are based on the Digital Soil Map of the World (FAO-UN, 2007) at 1:5,000,000 scale. Four textural classes were identified: coarse, medium, medium-fine and fine. Reference values of physical soil characteristics depending on its texture are taken from Israelsen and Hansen (1965) and Gómez del Campo and Fernandez (2007). The initial soil moisture content of each year is estimated using a ratio between the total available water content to the sum of the precipitation of November and December from the previous year.

ii) Green and blue water footprint of olives orchards

Representative meteorological stations located in the major crop producing regions are selected depending on data availability. Monthly reference evapotranspiration (ET_o) and precipitation for each of the provinces is obtained from the National Meteorological Agency (AEMET, 2010). These data have been completed with the Integral Service Farmer Advice for the years 2007 and 2008 (MAPA, 2010).

Required crop parameters have been reviewed (FAO, 2006; Lorite et al., 2004; Orgaz et al., 2005), making a distinction between rainfed and irrigated olive (See Appendix 1). It is assumed constant tree densities and crown volume for rainfed (100 trees/ha and 9,000 m^3/ha) and irrigated orchards (200 trees/ha and 9,000 m^3/ha). Root depth is assumed to be 0.6 m since most of the roots are located at this depth (Connell and Catlin, 1994). Once climate data, crop parameters and dominant soil texture class per province were determined CROPWAT calculations were performed. Within the CROPWAT model, the 'irrigation schedule option' was applied, which includes dynamic soil water balance and keeps track of the soil moisture content over time (FAO, 2006; 2009).

Rainfed production is 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:

$$ET_{green\ ij}\ (irr{=}0) = ET_{tot\ ij}\ (irr = 0) \qquad [4]$$

$$ET_{blue\ \ ij}\ (irr = 0) = 0 \qquad [5]$$

Where:

$ET_{green\ ij}$ *(irr=0)*: Green water evapotranspiration (mm) in the rainfed scenario in the province *i* and year *j*.

$ET_{blue\ \ ij}$ *(irr=0)*: Blue water evapotranspiration (mm) in the rainfed scenario in the province *i* and year *j*.

$ET_{tot\ ij}$ *(irr=0)*: Total water evapotranspiration (mm) in the rainfed scenario in the province *i* and year *j*.

The irrigation scenario (irr = 1) was applied with different irrigation timings, depending on the irrigation schedule. For our estimations we did not assume 'optimal irrigation' conditions since this is not practical for olive agricultural practices. The total water evapotranspiration is equal to ET_a over the growing period (i.e. actual water use by crop). The blue water evapotranspiration is equal to the 'total net irrigation' as specified in the model. The green water evapotranspiration is equal to the total water evapotranspiration minus the blue water evapotranspiration, as simulated in the irrigation scenario:

$$ET_{blue\ ij}(irr = 1) = Total\ net\ irrigation \qquad [6]$$

$$ET_{green\ ij}\ (irr = 1) = ET_{a\ ij}\ (irr = i) - ET_{blue\ ij}(irr = 1) \qquad [7]$$

Where:

$ET_{blue\ ij}(irr=1)$: Blue water evapotranspiration (mm) in the irrigated scenario in the province i and year j.

$ET_{green\ ij}\ (irr=1)$: Green water evapotranspiration (mm) in the irrigated scenario in the province i and year j.

$ET_{a\ ij}$: Total water evapotranspiration (mm) in the province i and year j.

Comparing data from AQUAVIR (2005) and the Agricultural Statistics Yearbook (MARM, 2010a) the Guadalquivir basin comprised approximately 88% of the irrigated olive area in Spain in the year 2004. Therefore, the irrigation water volume is calculated according to the Guadalquivir river basin situation. The volume of irrigation water used is based on the Special Action Plans for Alert and Temporary Drought in the Guadalquivir Basin (CHG, 2007). Each year during the period 1997-2008 is classified in relation to its water stored and drought level, which indicates what saving in agricultural water use is required. To establish the level of drought the management system "General Regulation" of the Guadalquivir basin has been analysed (MARM, 2008a) since it included nearly 70% of irrigated water use for agriculture in the Guadalquivir basin and 227,000 ha of olive trees in 2004 (CHD, 2007). Estimated water allowances depend on the drought level and are calculated based on the olive orchards allowance of 2,281 m^3/ha in 2005 within the Guadalquivir basin (*ibid*). The origin of blue water has been estimated based on the Inventories of Irrigated Land in Andalusia (Regional Government of Andalusia, 1999; 2003; 2008; Corominas, J 2010, pers. comm., 29 June).

Two irrigation schedules were established according the estimated water allowances and 90% field efficiency for drip systems (Strosser et al., 2007). The first one applies 2,380 m^3/ha for no drought (years 1997-1998 and 2001-2004) and prealert situations (years 1999 and 2005). Depth application is 2 mm with an irrigation timing of every three days between 1st March-31st May and every two days during 1st June-31st October. The second irrigation schedule applies 1,670 m^3/ha for alert level of drought (years 2000 and 2006-2008). The same application depth of 2 mm is used but irrigation timing is every four days between 1st March-31st May and every three days 1st in June-31st October. Although 2005 is the driest year of the period in the Guadalquivir basin, with an annual precipitation of 307 mm (MARM, 2008a), reservoir levels in the "General Regulation" management system only indicated prealert situation.

The 'green' water footprint of the crop per unit (m^3/ton) has been estimated as the ratio of the green water consumption (m^3/ha) to the crop yield (ton/ha). The green water consumption is obtained by summing up separately the green water evapotranspiration over the growing period of rainfed and irrigated systems. The green water consumption includes the proportion of the green water evapotranspiration of each textural class. The green water footprint in m^3 is calculated multiplying the final green water consumption over the growing period and the crop area. Similar calculations were applied to obtain the blue water footprint per unit (in m^3/ton) and total (in m^3). The inclusion of water consumption depending on the textural class is a refinement of the method of Hoekstra et al. (2009):

$$WF_{greenjkl}(m^3/ton) = \frac{10 \times \sum\left(ET_{greeni} * P_i\right)_{jkl}}{Y_{jkl}} \quad [8]$$

$$WF_{greenjkl}(m^3) = 10 * \sum(ET_{greeni} * P_i)_{jkl} * A_{jkl} \quad [9]$$

$$WF_{bluejk(m^3/ton)} = \frac{10 \times \sum(ET_{blue\ i} * Pi)_{jk}}{Y_{jk}} \quad [10]$$

$$WF_{bluejk}\left(m^3\right) = 10 * \sum(ET_i * P_i) * A_{jk} \quad [11]$$

Where:

$WF_{green\ jkl}$: Green water footprint (m^3/ton) of the province *j*, in the year *k* and under the production system *l*.

$\sum (ET_{green\ i} * P_i)_{jkl}$: Green water evapotranspiration (mm) of the province *j*, in the year *k* and under the production system *l* according to the proportion of each textural class *i*.

Y_{jkl}: Crop yield (ton/ha) in the province *j*, in the year *k* and under the production system *l*.

A_{jkl}: Crop area (ha) in the province *j*, in the year *k* and under the production system *l*.

$WF_{blue\ jk}$: Blue water footprint (m^3/ton or m^3) of the province *j,* in the year *k* under irrigation conditions.

$ET_{blue\ jk}$: Blue water evapotranspiration (mm) of the province *j*, in the year *k* under irrigated conditions.

Y_{jk} : Crop yield (ton/ha) in the province *j*, in the year *k* under irrigated conditions.

A_{jk}: Crop area (ha) in the province *j*, in the year *k* under irrigated conditions.

Area and yield data were obtained from the Agricultural Statistics Yearbooks (MARM, 2010a), except for the area of irrigated olive orchards in Andalusia that has been interpolated using the Inventories of Irrigated Land in Andalusia of 1997, 2002 and 2008 (Regional Government of Andalusia, 1999; 2003; 2008) (See Appendix 2).

iii) Grey water footprint of olive groves

Finally, the 'grey' water footprint of a primary crop is an indicator of the degree of freshwater pollution associated with the production of the crop (Hoekstra et al., 2009). As it is generally the case, the production of olives concerns more than one form of pollution. The grey water footprint has been estimated for nitrogen since it is a very dynamic element which can be the source of surface and groundwater pollution caused by leaching (Fernández-Escobar, 2007). The grey water footprint can be expressed as following:

$$WF_{grey\ ijk}\,(m^3/ton) = \frac{\mathrm{WF}_{\mathrm{grey\,ijk}}\,(million\,\mathrm{m}^3) * 10^{\wedge}6}{\mathrm{Pr}_{\mathrm{ijk}}} \qquad [12]$$

$$WF_{grey\ ijk}(million\ m^3) = \frac{N_{surp} * A_{ijk} * 10^{-3}}{(c_{\max} - c_{nat})} \qquad [13]$$

Where:

$WF_{grey\ ijk}$: Grey water footprint (million m^3 or m^3/ton) of the province *i*, in the year *j* under the production system *k*.

Pr_{ijk}: crop production (tons) of the province *i*, in the year *j* under the production system *k*.

N_{surp}: Nitrogen surplus (kg/ha).

C_{max}: the maximum acceptable concentration (50 mg NO_3/liter).

C_{nat}: natural concentration in the receiving water body (mg/l).

A_{ijk}: Crop area (ha) in the province *i*, in the year *j* under production system *k*.

Modifications of the method of Hoekstra et al. (2009) are made since the grey water footprint is calculated based on nitrogen surplus instead of the chemical application rate per hectare times the leaching fraction. Nitrogen surplus, difference between nitrogen inputs and outputs in agriculture, can be a good indicator of potential losses to the environment at global, local or farm scale (European Commission, 2002). Nitrogen balances of 2006 have been used to determine the nitrogen surplus in olive orchards for each province as calculated by the Ministry of the Environment and Rural and Marine Affairs of Spain (MARM, 2008c). Nitrogen surplus is constant throughout the years for each province and does not differentiate between rainfed and irrigated olives. The nitrogen balance gives a mean of nitrogen surplus for both olive production systems.

An ambient water quality standard of 50 mg NO_3/liter of water is used to calculate the water volume necessary to assimilate the load of pollutants following the Nitrates and Groundwater Directives (EU, 1991; 2006). The natural concentration of pollutants in the receiving water body has been assumed negligible.

2.1.2. Supply chain water footprint related to other product components

The supply chain water footprint of olive oil is not only made up of ingredients but also of other components that form the whole product. Other main components of the product are gathered in Table 1. For the calculation of the water footprint related to other components, the water footprint of raw material and process water requirements are taken into account separately. We only assume water footprint of other components for bottled olive oil.

TABLE 1. *Water footprint of raw material and process water use of other product components*

Components	*Raw material*	*Grams*[1]	*Water footprint raw material*[2] *(m^3/ton)*			*Process water use*[2] *(m^3/ton)*		
			Green	*Blue*	*Grey*	*Green*	*Blue*	*Grey*
Bottle - PET[3]	Oil	39	0	10	0	0	0	225
Cap - HDPE[4]	Oil	3	0	10	0	0	0	225
Label - PP[5]	Oil	0.3	0	10	0	0	0	225

[1] Source: Grams estimated for 1 liter bottle from Ercin *et al*. (2009)
[2] Source: Van der Leeden *et al*. (1990)
[3] PET: Polyethylene terephthalate
[4] HDPE: High density polyethylene
[5] PP: Polypropylene

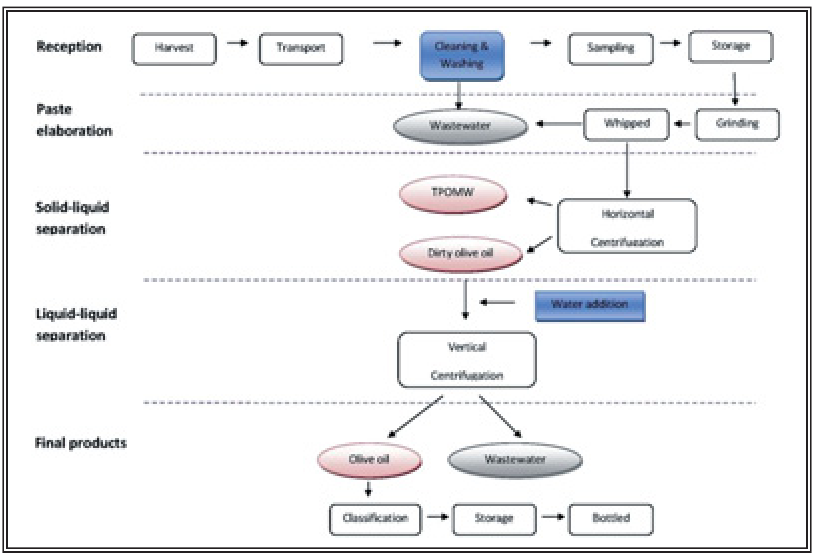
2.2. Operational water footprint

The operational water footprint is defined as the amount of freshwater used at a specific business unit, i.e. the direct freshwater use.

$$WF_{\textit{operational}} = WF_{\textit{operational [ingredients]}} + WF_{\textit{operational [other parts]}} \quad [14]$$

In this study, the operational water footprint of olive oil ($WF_{operational}$) includes the direct operational water required during the production of virgin olive oil as illustrated in Figure 2. Refined olive oil fraction process, which treats virgin olive oil and cannot be directly consumed owing to severe quality alterations (Uceda, 2009), is not studied. New tech-

FIGURE 2. *Main phases, processes and subproducts during olive oil production. Blue water application and grey water generation are highlighted.*



Source: Own elaboration.

nology for olive oil extraction is a centrifuge two phase process that generates a liquid phase (dirty olive oil) and an organic slurry known as two-phase olive mill waste (TPOMW) (López-Piñeiro et al., 2010). The two phase system has been analysed, since it comprises 93% of olive oil production in Spain (Alba et al., 2009). Most data related to the operational water footprint of olive oil are taken from Alba et al. (2009) and Caputo et al. (2003).

Below are detailed the phases and processes that require water addition. During all these processes, the amount of water lost (evaporated) is assumed to be zero.

1. At the reception phase olives are cleaned and washed, if they are picked up directly from the ground or have residues such us dirt, mud or fertilizers. Wash machines use abundant water in a close recirculation system. During this phase the blue water applied was assumed to have the same volume as the wastewater generated, which comprises 0.05 l per kg of olives.

2. The solid & liquid separation phase contains a system of two phase decanter with two independent outlets for the TPOMW (mixed of water vegetation and solids) and dirty olive oil, respectively. The two phase decanter does not need water addition as far as olive paste has a minimum moisture content of 50-53%. If this moisture content is not achieved owing to climatic conditions or olives maturity, the necessary fraction of water would be replaced. Blue water footprint is zero since the minimum moisture content is assumed to be met.

3. The liquid & liquid separation consists of a vertical centrifugation to remove solid and liquid residues of the olive oil. Water addition helps to separate olive

oil from dirt obtaining a fraction of cleaned olive oil and another of wastewater. The water applied at this stage generates at the same time a final wastewater discharge of 0.1-0.15 l/kg. The blue water applied has been assumed to be equal to the volume of wastewater generated.

4. In addition, the blue water for cleaning of equipment becomes to wastewater with 0.05 l/kg.

During the processes mentioned above a total wastewater of 0.20-0.25 l/kg is generated. It is assumed that all wastewater is treated with 100% treatment performance and effluent characteristics of the treated wastewater are within the legal limits. With this assumption, the grey component of the operational water footprint is considered to be zero. The only fraction of blue water that is consumed is due to water evaporation in evaporation ponds. The volume of water evaporated depends on the climatic conditions and suspended oil content. This part was not included since it represents a small fraction of the total water footprint and no estimates were found. The blue water footprint is therefore assumed to be zero. However, further research is needed in this area.

2.3. The water footprint of crop products

The water footprint of crop products (i.e. olive oil) is calculated by dividing the water footprint of the input product (i.e. olives from olive oil trees) by the product fraction (Garrido et al., 2010; Hoekstra et al., 2009). The latter is defined as the quantity of the output product obtained per quantity of input product. If processing involves some water use, the process water use is added to the water footprint of the input product before the total is distributed over the various output products. Processing water has been taken into account during the olive oil production ($WF_{operational}$).

In the present study the product fraction calculation is based on the industrial olive oil yield (Ruiz, 2001), which is known as the olive oil obtained per kilogram of milled olives. The olive oil content depends on the growing conditions and genetic variety, but not on the fruit size and level of crop yield (Lavee and Wodner, 2003). We have not distinguished type of year and variety of olive tree assuming an olive yield content of 22% for normal climate year according to Pastor et al. (1999) and assumed 50% olive moisture content. A product fraction of 19.6% is obtained.

$$p_f = \frac{\left[OYC-(100-OYC-H)\times F\right]}{100} \qquad [15]$$

Where:

p_f: Product fraction (%)

OYC: Olive yield content (%)

H: Moisture content of olives (%)

F: Loss of oil during milling (0.087)

As a result, the water footprint of 1 litre olive oil can be expressed as follows:

$$WF_{oliveoilijk} = \left(\frac{WF_{olives\ ijk}}{p_f}\times d\right) + WF_{sup\ ply-chain}\left[other\ parts\right] + WF_{operational} \qquad [16]$$

Where:

WF $_{olive\ oil\ ijk}$: Water footprint olive oil (l/l) in the province i, year k and under production system k.

$WF_{olives\ ijk}$: Water footprint olives (l/kg) in the province i, year k and under production system k.

d: density of olive oil (0.918 kg/l).

2.4. Apparent water productivity of olive oil

The concept of apparent water productivity is used to assess the economic efficiency of the water consumed per ton of olive oil produced. Market prices for each province are determined taking into account the production and price of the 3 types of virgin olive oil: extra, fine and normal virgin olive oil (MARM, 2010a).

$$AWP_{jkl}=\frac{\sum(Pr_i * T_i)_{jk}}{WF_{jkl}} \qquad [17]$$

Where:

AWP_{jjk}: Apparent water productivity (€/m^3) of the province j, in the year k and under production system l.

$\sum (Pr_i * T_i)_{jk}$: market price (€/ton) of the province j, in the year k according to the proportion of the type of olive oil production in the corresponding year.

WF_{ijk}: water footprint olive oil (m^3/ton) of the province i, in the year j and under production system k.

2.5. Virtual water exports of olive oil

The olive oil virtual water exports indicate the water embedded in exports. The green and blue virtual water exports have been analysed as follows:

$$WF_{green\ exp\ ij} = WF_{greenij}(m^3/ton) * E_{ij} * 10^{\wedge -6} \quad [18]$$

$$WF_{blue\ exp\ ij} = WF_{blueij} \times E_{ij} \quad [19]$$

Where:

$WF_{green\ exp\ ij}$: Green virtual water exports (million m^3/year) of the province *i,* in the year *j*.

$WF_{blue\ exp\ ij}$: Blue virtual water exports (million m^3/year) of the province *i,* in the year *j*.

E_{ij}: Exports (ton/year) of the province *i,* in the year *j*.

Main olive oil producing provinces do not match with the major olive oil exporting provinces, because of internal trade within Spain. Virtual water exports of olive oil are based on the weight of each province to the national olive oil production in order to take into account where the olive oil production comes from.

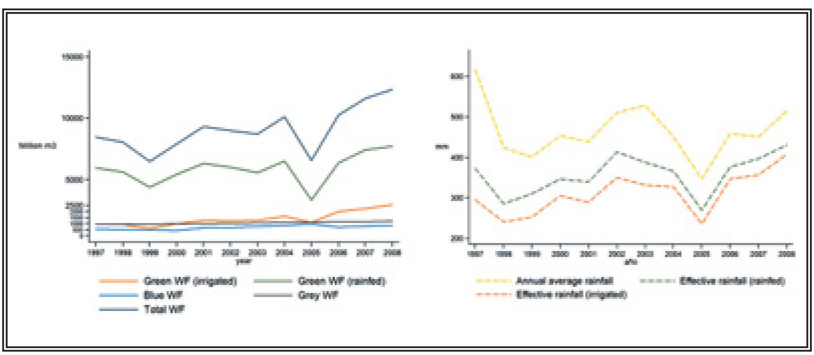
3. Results

3.1. Water footprint of olives orchards

The water footprint of olive orchards (for oil and table production) in terms of million m^3 refers to the volume of water consumed or polluted. The main factors influencing the water footprint are crop area, rainfall and irrigation volume. As shown in Figure 3, in the analysed period there is a clear trend of total water footprint growth. The green water footprint of rainfed olives is significantly larger than the irrigated one, probably because the former comprises from 7.4 to 3.5 times the irrigated area, at the beginning and end of the period of study. In the case of grey water footprint, variations rely uniquely on the area expansion because the same value of nitrogen surplus has been used for each year. There seems to be a correlation between the total annual water footprint and yearly rainfall, but the effective precipitation is higher in rainfed orchards than in irrigated ones. The lowest annual rainfall in 2005 (with 430 mm) is clearly reflected in the decrease of the green water footprint both under rainfed and irrigated conditions. The blue water footprint dropped in 2000 and 2006-2007 owing to the estimated water allowance of 1 670 m^3/ha for the mentioned years due to the drought situation prevailing in the Guadalquivir basin.

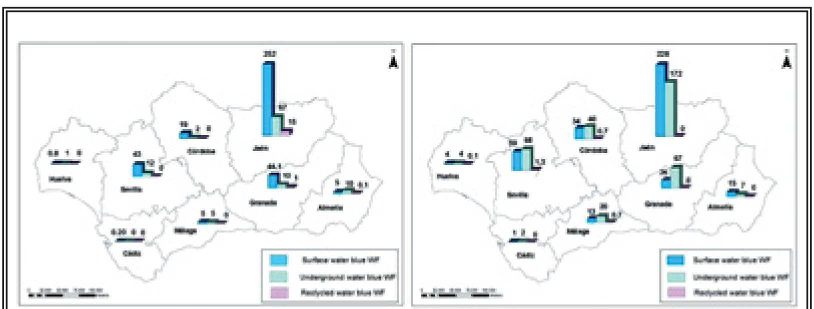
During the study period Andalusia comprises 86% of the national blue water footprint of olive production in Spain,

FIGURE 3. *Total green, blue and grey water footprint of olive production in Spain in million m^3 (left) and annual average rainfall and effective rainfall in mm (right) for the period 1997-2008.*



reaching in 2008 a blue water footprint of 761 million m^3. In 2008 only 13% of national blue water footprint of olives is allocated to olive table production. In the mentioned year, Sevilla is distinctly the most important olive table producing province consuming 82 million m^3 of blue water, 64% of the blue water footprint within the province. Surface water irrigation for olive orchards decreased in Andalusia from 66 to 43% in relation to the national blue water footprint over the study period. In contrast, groundwater resources have been increasingly consumed from 19 to 43%, growing abstractions from 106 (1997) million m^3 to 378 million m^3 (2008) (Figure 4). Jaén is the first blue water consumer in Andalusia, and also in Spain with 401 million m^3 in 2008, of which 99% belongs to olives for olive oil production. Between 1997 and 2008 surface water consumption moderately decreased and groundwater resources consumption more than doubled in the province. Granada and Córdoba, with 99% and 94% of the blue water footprint of olives for olive oil, presented lower blue water consumption than Jaén, but they also significantly expanded their groundwater footprint between 1997 and 2008. As a matter of fact, in 2008

FIGURE 4. *Origin of blue water footprint: surface, groundwater and recycled in million m^3 for 1997 (left) and 2008 (right).*



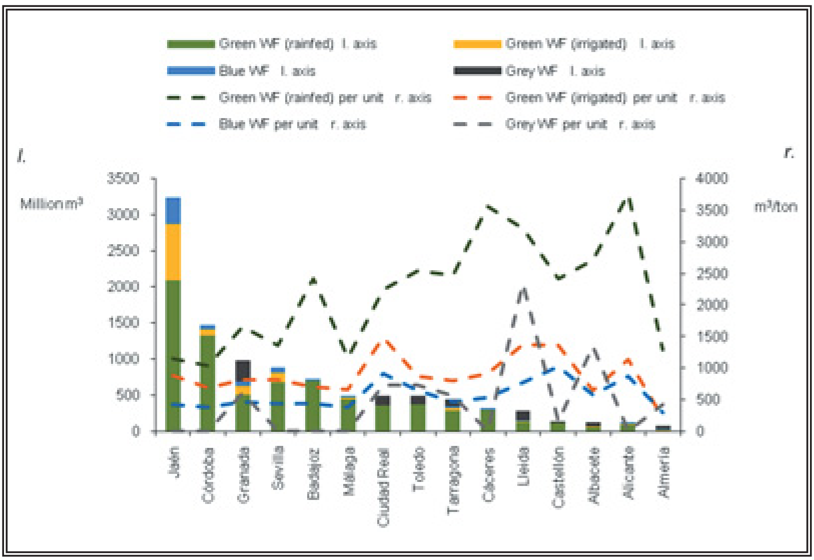
Source: own elaboration based on the Inventory and Characterisation of Irrigated Land in Andalusia of 1997, 2002 and 2008 (Regional Government of Andalusia, 1999; 2003; 2008).

most provinces increased groundwater consumption for olive production with the exception of Almería.

The water footprint in m³/ton points out the crop water efficiency or nitrogen pollution potential per unit of crop produced. More efficient and less nitrate pollution potential, of olive orchards is related to lower water footprints. For the studied period Spain presents the following average water footprint per unit: 1 971 m³/ton green water footprint (rainfed), 859 m³/ton green water footprint (irrigated), 434 m³/ton blue water footprint and 190 m³/ton grey water footprint. Appendix 3 gathers the water footprint of olive orchards in m³/ton for each province over the period 1997-2008.

Figure 5 compares the total water footprint and the water footprint per unit of crop for the main olive producing

FIGURE 5. *Green, blue and grey water footprint in million m³ and m³/ton of the main olive producing provinces in 2001.*



provinces for a normal year (2001). Only provinces that comprise ≥1% of the national olive production in 2001 are illustrated. In 2001, Jaén, Córdoba and Sevilla represent 69% of the national olive production and 49 % of the national water footprint of olive production with 3 237, 1 462 and 880 million m^3 respectively. While their total water footprints in million m^3 are the largest, they are very efficient in terms of green and blue water use (m^3/ton). Based on the nitrogen balance applied, Jaén, Córdoba and Sevilla do not generate any grey water footprint. The provinces that present the highest nitrogen pollution per ton of crop produced (m^3/ton) are minor olive producers such as Lleida, Albacete and Toledo.

3.2. Water footprint of olive oil

The water footprint of olive oil includes the supply chain water footprint, which is the sum of the water footprint of ingredients and other components, and the operational water footprint. The supply chain water footprint related to other components for olive oil production does not represent more than 0.5% to the total supply chain for each year and province of study. In the operational water footprint assessment one litre of olive oil can generate 0.9-1.2 litres of wastewater, taking into account a product fraction of 19.6 % and olive oil density of 0.918 kg/l. It has been assumed that the blue water does not evaporate and becomes wastewater, which is completely treated. According to the assumptions made, the operational water footprint has a value of zero.

In conclusion, most of the water used (consumed and polluted) to produce olive oil occurs in the supply chain, particularly due to olive production in the field. Table 2 presents the water footprint of olive oil in million m^3 during the period of study. In colour terms of types of water consumption, the water footprint components can be summarised as follows: 71% green water footprint from rainfed systems, 12% green water footprint from irrigated ones, 7% blue water footprint and 10% grey water footprint.

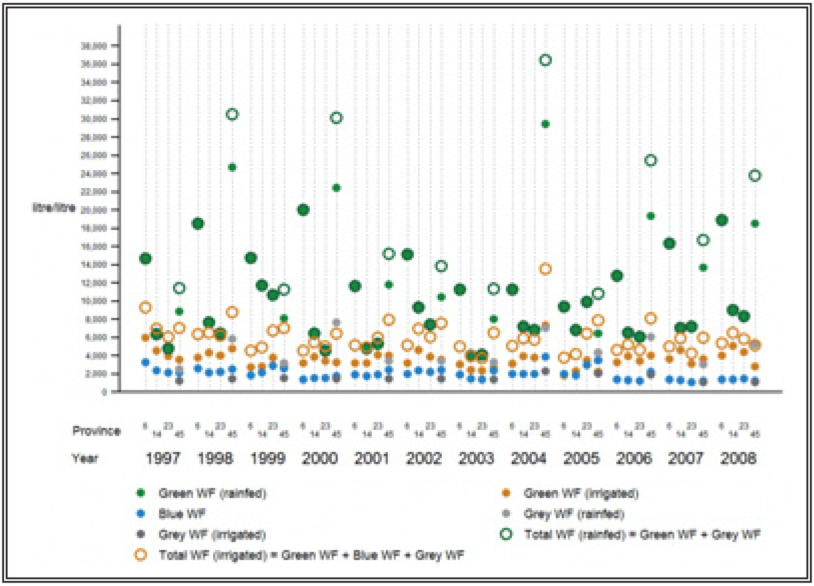
Spain has the following annual ranges of the water footprint per liter of olive oil produced: 8 253 - 13 468 l/l green water footprint (rainfed), 2 789 - 4 634 l/l green water footprint (irrigated), 1 428 - 3 002 l/l blue water footprint (irrigated) and 712 - 1 509 l/l grey water footprint (rainfed & irrigated). These ranges are weighted averages according to the share of each province to the national production. The blue water footprint of other components in rainfed olives has a negligible value of 0.4 l/l. The water footprint of olive oil in l/l for each province over the period 1997-2008 is resumed in Appendix 4.

The water footprint in l/l is resumed for four typical olive oil producing provinces in Spain (Figure 6). In this figure the blue and grey water footprints of other components are included in the totals of their respective colour component and total water footprint. The blue water footprint of rainfed olives is considered as negligible and is not illustrated in Figure 6. The great variation of the total water footprint in l/l of rainfed olives over the study period is remarkable, ranging from 4 111 of water per litter of oil in Córdoba in 2003 up to 36 866 l/l in Toledo in 2004. The main reason is the different climatic conditions and crop yields among provinces. Among provinces rainfed olive oil water footprint from Jaén and Córdoba outstands from those of Badajoz and Toledo. The total water footprint of irrigated olive oil varies to a lesser extent between 3 820 (Jaén in 2003) and 14 502 l/l (Toledo in 2004), probably because crop production is not so strongly affected by rainfall. From the selected provinces, Toledo is the only one that presents a grey water footprint

TABLE 2. *National water footprint of olive oil in million m^3 during the period of study*

	Year	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*
Ingredients	Green WF (rainfed)	7,560	7,207	5,942	6,903	7,824	7,535	7,092	8,016	5,046	7,836	8,852	9,119
	Green WF (irrigated)	907	866	542	915	1,185	1,139	1,140	1,409	9,86	1,720	1,943	2,208
	Blue WF	514	502	440	415	623	648	711	777	859	657	709	778
	Grey WF	967	943	978	993	1,010	1,024	1,078	1,115	1,130	1,151	1,159	1,207
Other components	Blue WF (rainfed)	0.4	0.3	0.2	0.3	0.5	0.3	0.5	0.3	0.2	0.3	0.4	0.3
	Blue WF (irrigated)	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.2	0.2
	Grey WF (rainfed)	9.7	6.6	4.8	7.7	10.5	6.1	10.7	7.0	5.2	7.6	8.3	7.6
	Grey WF (irrigated)	2.1	1.9	1.4	2.2	2.9	2.3	3.9	3.0	2.7	4.1	4.7	4.6
Total		9,961	9,526	7,908	9,236	10,656	10,355	10,036	11,328	8,028	11,377	12,677	13,325

FIGURE 6. *The water footprint of olive oil in l/l for four typical producing provinces. Provinces are coded as follow: 6 = Badajoz, 14 = Córdoba, 23 = Jaén and 45 = Toledo.*

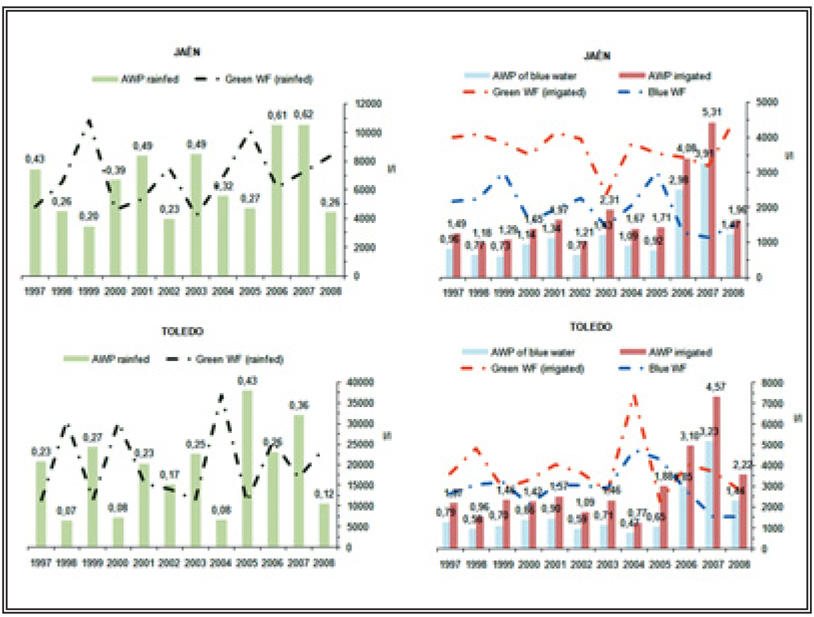


in rainfed conditions ranging from 2 578 in 1997 to 7 706 l/l in 2004 and in irrigated systems ranging from 1 302 to 2 326 l/l in the same mentioned years.

3.3. Apparent water productivity (AWP) of olive oil

To analyze the AWP (€/m^3) of olive oil two typical producing provinces, Jaén and Toledo, have been studied (Figure 7). The apparent water productivity (for each province over the period 1997-2008 is gathered in Appendix 5. The AWP seems to be inversely related to the water footprint per unit of olive oil and fluctuates in a similar way over the period in both production systems, probably owing to the variation of olive oil market prices. Nevertheless, the more frequent variations from year to year of the green water footprint in rainfed conditions cause a staggered trend of the AWP. In rainfed systems the AWP of olive oil ranges from 0.20 to 0.62 €/m^3 in Jaén and from 0.07 to 0.43 €/m^3 in Toledo. AWP of irrigated systems has a relatively stable trend between 1997 and 2005 with values below 2.31 and 1.88 €/m^3 in Jaén and Toledo respectively. The peaks of AWPs in 2006 and 2007 are related to highest olive oil prices of 4,119 (2006) and 4,868 (2007) €/ton in Jaén and 5,525 (2006) and 5,436 (2007) €/ton in Toledo. Greater olive oil prices in Toledo are caused by its larger extra virgin olive oil production.

FIGURE 7. *Olive oil water footprint and apparent water productivities for rainfed (left) and irrigated (right) production systems in Jaén (top) and Toledo (bottom) over the period 1997-2008.*

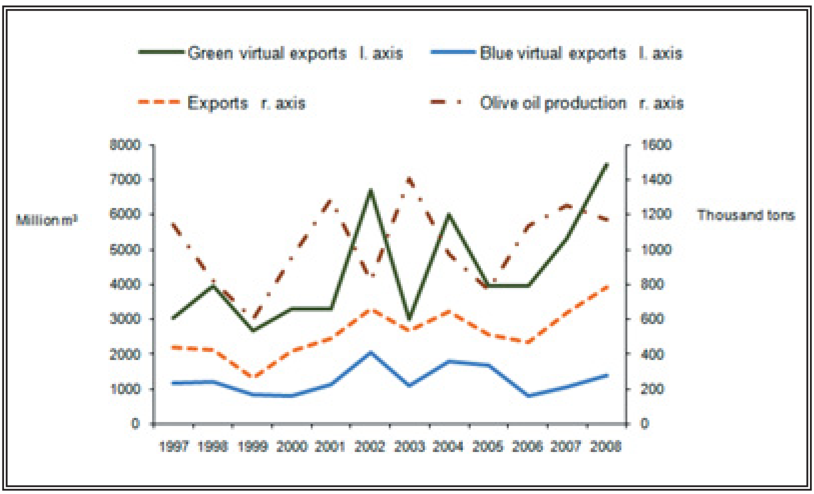


3.4. Virtual water exports of olive oil

According to the information from the Olive Oil Agency (OOA, 2010b) exports comprise 55% of the total national olive oil production between 2005/2006 and 2007/2008 agricultural seasons. Differences between production and exports of olive oil are based on the final stocks of each agricultural season. For instance, in 2002 olive oil production was not significant but final stocks of the olive oil produced in 2001 were exported. Then the fall of olive oil production in 2002 is reflected in the decline of exports in the following year (Figure 8).

The present report shows that the green water is the main component in most virtual water exports, amounting to 77% of the total virtual water exports between 1997 and 2008. Differences among years are very significant, green water being the most unstable component, which is closely

FIGURE 8. *Green and blue virtual water exports (million m³), exports (million tonnes), and olive oil production (million tonnes).*



dependent on precipitation. Note, however, that blue virtual water exports are much more stable. Rainfed olives therefore have an important role in virtual water exports, even if the area of irrigated olive trees, and the related blue water footprint, has increased during the period of study.

4. Discussion

The total water footprint of olive orchards in Spain ranges from 8 483 (year 1999) to 14 369 (year 2008) million m^3 during the studied period. The growth of the national water footprint over the period is mainly due to new olive plantations. The green component of the rainfed olives comprises the largest proportion of the water footprint owing to the greater extension of this production system. In irrigation practice effective rainfall is the portion of the total precipitation which is retained by the soil so that it is available for use for crop production (FAO/IPTRID/ICID/ODA, 2000). According to our Cropwat results, effective rainfall is higher in rainfed orchards than in irrigated ones since the irrigation water application lowers the green water evaporated. However, once water is stored in the soil it is not possible to distinguish between blue and green components. The present report shows higher values for the national green water footprint of olives than those (8,900 in contrast to about 2,000 million m^3) estimated by Garrido et al. (2010).

On the other hand, the water footprint per unit of crop produced can illustrate the efficiency of water consumption in relation to crop production. In our study the water footprint per unit of rainfed olive orchards (green) is usually higher (about 1 971 m^3/ton) than the irrigated one (green plus blue) (around 1 293 m^3/ton) owing to lower crop yields. In rainfed olive trees, the rainfall and temperature patterns contribute to the fruit production, whereas irrigated olive orchards production depends mainly on temperature since water stress is usually avoided by the irrigation water supply (Lavee, 2007). In addition, olive trees are characterised by a negative relation of the crop yield in a present year and that in the following one known as alternate bearing (*ibid*). Modifications in olive systems such as new plantations and conversion to irrigated crops should also be considered for crop yield variation among years. Despite the fact that green water consumption depends on precipitation, low yields per ha of rainfed olives seem to point to a transition towards more productive olive orchards. However, problems related to diversity losses and environmental pressures arise with more intensive agricultural systems of olive orchards (MARM, 2007; Scheidel and Krausmann, 2011) and rainfed olive production saves the scarce blue water resources.

Aldaya and Llamas (2009) estimated the green and blue water footprint per unit for olive orchards in the Guadiana river basin. In line with their study, in 2001 the green water footprint has a value of 600 m^3/ton and 210 m^3/ton for rainfed and irrigated systems respectively, and a value of 750 m^3/ton of blue water footprint in the Middle Guadiana basin, which contains Badajoz and Caceres provinces. The present study shows in rainfed conditions significantly greater green water footprints (2 410 and 3 540 m^3/ton for Badajoz and Cáceres). Irrigated systems indicate higher green water footprint (700 and 900 m^3/ton for Badajoz and Cáceres) and lower blue water footprint (430 and 520m^3/ton for Badajoz and Cáceres) in 2001, in spite of using similar crop yields in both studies. These differences in the results could be due to methodological improvements: the present study takes into account soil water content and does not assume optimal irrigation conditions. In any case, we should also bear in mind that the scale of our study is larger than in the case of Aldaya and Llamas (2009), which could lead to greater dispersion on the results.

To determine the irrigation schedule of olive orchards we should consider factors such as precipitation, evapotranspiration, type of soil, density of the plantation and volume of canopy (Orgaz *et al*., 2005). However, the study scale and availability of data do not allow us to take into account these considerations. Water scarcity in the Guadalquivir basin does not permit fulfilling the water allowances every irrigation season (Camacho et al. 2007). Depending on the prevailing climatic and hydrological conditions, farmers receive different water allowance volumes for each irrigation season. The Inventory and Characterisation of Irrigated Areas in Andalusia indicates a gross water use of olive trees at field level in the Guadalquivir Basin of 2440 m^3/ha for an average climate year (Regional Government of Andalusia, 2003). This value is in accordance with the estimated water allowances for no drought and pre alert years without irrigation restriction. In any case, improvements on the blue water consumption of olives can be achieved since our estimated water allowances only includes the system of exploitation "General Regulation" and do not consider non regulated surface water and illegal groundwater wells. Berbel (2009) states that by 2015 in the Guadalquivir basin 300 million m^3 of the water used will be non regulated surface water and illegal groundwater wells, which comprises 17% of the total water consumption in the basin. In addition, the scale of our study does not enable to take into account farmers' decisions which consider the precipitation during irrigation management, assuming that rainfall is sufficient and reducing their irrigation schedules (García-Vila *et al*., 2008). Adoption of good irrigation practices, which take into account the type of soil and precipitation, would enhance blue water productivity of irrigated olives.

The total water footprint of one liter of olive oil depends mainly on the supply chain water footprint of olives. In fact the supply chain water footprint for other components (bottle, cap and label) comprises no more than 0.5% of the supply chain water footprint; a small fraction also reported in previous studies (Ercin *et al.*, 2009). The operational water footprint of the product, representing a small amount and needing further study, has also been considered negligible. Life cycle assessment studies (Avraamies and Fatta, 2008) of olive oil production calculated that the water consumed during the olive oil processing stage only account for 1.4% of the overall water consumption.

Over the studied period Spanish olive oil production presents the following average percentage of water footprint color components: 71% green water footprint from rainfed systems, 12% green water footprint from irrigated ones, 7% blue water footprint and 10% grey water footprint. Variability of the water footprint per unit among provinces depends mainly on the type of production system and year, being the supply chain water footprint of the olives key to improve water management. The value of 15 831 m^3/ton provided in Chapagain and Hoesktra (2004) during the period 1997-2001for virgin olive oil in Spain, which is equivalent to 14 533 l/l, is significantly larger than those obtained in this study, particularly in irrigated conditions. This is probably due to the fact that they assumed that the crop water requirements are met and did not take the soil water balance into account.

To establish the crop coefficients, we have assumed determined tree densities and crown volumes for rainfed and irrigated systems. Outstanding values of green water footprint of olive oil such as in Toledo, which reaches 36 870 l/l in 2004, are mainly caused by very low crop yields. However, rainfed olive trees in Toledo probably present lower tree densities than the assumed 100 trees/ha. The water evaporation and therefore water footprint differ depending on the olive crown volumes and planting pattern. More accurate values could be obtained using site specific crop parameters.

Based on the grey water footprint results, the main olive oil producing provinces do not seem to represent significant sources of nitrate pollution. Olive orchards do not cause excessive nitrogen surplus in soil because the crop is able to absorb most of the applied nitrogen fertilizer. For instance, the Guadajoz and Jaen catchments (within the Guadalquivir basin) show the lowest nitrogen surplus per ha in Guadalquivir basin owing to olive orchards land use (Berbel and Gutiérrez, 2004). Jaén, the first olive oil producing province in Spain, presents a negative nitrogen balance (MARM, 2008c). This means there is a larger removal of nitrogen from the system (mainly because of harvest and pruning) than application (mostly as mineral and organic fertilization).

The grey water footprint (l/l) of irrigated systems shows lower values than the rainfed ones. However, the differences of grey water footprint between production systems should be considered as a first approximation because the data of nitrogen surplus used do not differentiate between rainfed and irrigated olives. In practice, nitrogen inputs of irrigated olives are nearly three times higher than rainfed ones (IDAE, 2007). Consequently, a nitrogen balance that differentiates between these two olive production systems would help to improve the quality of the grey water footprint analysis. Further research of grey water footprint also needs to focus both on spatial and temporal variation of pollutants. Higher concentrations of nitrates in water bodies would be expected after fertilization practice followed by rainfall gages (Rodríguez-Liziana et al., 2005). Nitrate concentrations would also be higher in the dry season than in the wet one (Angelopoulos et al., 2009).

AWPs under rainfed conditions fluctuate in a greater extent than under irrigated ones because of their large crop yield variations from year to year. To assess the economic performance of a product, both the water footprint and market price variations, as occurred in years 2006 and 2007, are relevant.

Finally, the olive oil virtual water exports show the water embedded in exports. Virtual water exports in the form of exported olive oil vary across years, and are mostly depend on the green water, which denotes the importance of the green water in the virtual water trade, as reported in previous studies (Aldaya et al., 2010). Only 23% of virtual water exports of olive oil belong to irrigation water. Andalusia is the largest blue water consuming region in relation to olive production in Spain with an average of 86% during the period 1997-2008. In 2008 groundwater resources in Andalusia reached a value of 42% of the national blue water consumption. The increasing groundwater use is in a way related to the blue virtual water exports of olive oil. Consequently, if the blue virtual water exports related to olive oil tend to grow, the Guadalquivir basin may face further water stress, particularly from groundwater resources in the following years. In an irrigated district of Córdoba 18% of farmers consider olive trees as an alternative to current cropping patterns (García-Vila *et al.*, 2008). As a result further development of this crop in irrigated systems may be expected in the coming years.

5. Conclusion

It is not possible to provide a unique value of water footprint for olives and consequently for olive oil in Spain because several factors influence it. In our study the water footprint of olive oil has been estimated taking into account variables such as soil type, production system and variation over the time of climate conditions and water allowances.

The operational water footprint of the product, representing a small part of the total and in need of further study, has been considered zero. As a result, the supply chain water footprint comprises the total water footprint of the olive oil. Most of the supply chain water footprint of one litre of olive oil originates in the raw product (>99.5%), that is, during the olive growing process. A smaller fraction of the supply chain water footprint comes from the other components (<0.5%), mainly from the plastic based bottle, cap and label. The results of this study confirm the importance of a detailed supply chain assessment in water footprint accounting of ingredients in the case of agriculture based products.

The average water footprints of olive oil ranges in Spain are: 8 253 - 13 468 l/l green water footprint (rainfed), 2 789 - 4 634 l/l green water footprint (irrigated), 1 428 - 3 002 l/l blue water footprint (irrigated) and 712 - 1509 l/l grey water footprint (rainfed & irrigated). The different components of the total water footprint in million m^3 in the study period are as follows: 71% green water footprint from rainfed systems, 12% green water footprint from irrigated ones, 7% blue water footprint and 10% grey water footprint.

Virtual water exports of olive oil vary across years, and are mainly related to the green water footprints. Only 23% of virtual water exports originate from surface and groundwater abstractions. However, recent trends in the Guadalquivir basin (provinces of Jaén, Córdoba and Granada) indicate alarming growth in groundwater use, most of it used by olive growers. Our results suggest that virtual groundwater exports related to olive oil exports may add further pressure to the already stressed basin.

Variations of crop parameters would also influence the olive oil water footprint. There are other factors such as plantation density of trees, volume of crown and volume and timing of irrigation water that could not be taken into account in the present analysis. Further studies at local scale could make possible improvements in this area. In addition, further assessment of the economic, social and environmental aspects of the olive oil water footprint could improve the present report.

Acknowledgements

We would like to thank professor Mª Gómez del Campo and Carlos Hernández Díaz-Ambrona for their support and information provided. The contents of the report remain the responsibility of the authors.

References

AEMET (2010) Data supplied by the National Meteorological Agency. www.aemet.es/es/portada

Alba, J., Martínez, F., Moyano, M.J. and Hidalgo, F. (2009) Tecnología de Elaboración de aceite de oliva. In: J. Vilar (Coord.) Algunas contribuciones sobre olivicultura y Elaiotecnia desde la perspectiva de la experiencia. Jaén: GEA Westfalia Separator Andalucía S.L. 137-174 pp.

Aldaya, M.M. and Llamas, M.R. (2009) Water Footprint Analysis (Hydrologic and Economic) of the Guadiana River basin. The United Nations World Water Assessment Programme, Scientific Paper. United Nations Educational, Scientific and Cultural Organization, Paris.

Aldaya, M.M., Allan, J.A. and Hoekstra, A.Y. (2010) Strategic importance of green water in international crop trade. Ecological Economics 69: 887-894 pp.

Allan, J.A. 1999. Global systems ameliorate local droughts: Water, food and trade. Occasional paper 10. London: School of Oriental and African Studies.

Angelopoulos, K. Spiliopoulos, I.C., Mandoulaki, A. Theodorakopoulou, A. and Kouvelas, A. (2009) Groundwater nitrate pollution in northern part of Achaia Prefecture. Desalination 248: 852-858 pp.

Ansink, E. (2010) Refuting two claims about virtual water trade. Ecological Economics 69: 2027-2032.

AQUAVIR (2005) Superficie de los Cultivos de Regadío y sus Necesidades de Riego, en la Demarcación de la Confederación Hidrográfica del Guadalquivir. Convenio de Colaboración entre la Sociedad Estatal Aguas de la Cuenca del Guadalquivir S.A. y la Empresa Pública Desarrollo Agrario y Pesquero S.A. Available from: http://www.chguadalquivir.es/-opencms/portalchg/index.html [Accessed on June 2010].

Avraamides, M. and Fatta, D. (2008) Resource consumption and emissions from olive oil production: A life cycle inventory case study in Cyprus. Journal of Cleaner Production 16: 809-821 pp.

Berbel, J. and Gutiérrez, C. (2004) Estudio de sostenibilidad del regadío en el Guadalquivir. Feragua.

Berbel, J. (2009) Diagnóstico y avance de medidas en la cabecera Nordeste del Guadalquivir: Aspectos cuantitativos. Plan hidrológico de Demarcación. Participación Pública. Taller Territorial Cabecera Nordeste. Taller nº 12 (16.06.2009). [Online] Available from: http://www.chguadalquivir.es/-opencms/portalchg/planHidrologicoDemarcacion/participacionPublica/talleresJornadas/taller0010.html

Camacho, E., Rodríguez, J.A., Pérez, L. and Parias, P. (2007) Debilidad del regadío en la cuenca del Guadalquivir. Agricultura. 448-452 pp.

Chapagain, A.K. and Hoekstra, A.Y. (2004) Water Footprints of Nations. 2 Vol., Value of Water Research Report Series, nº 16, UNESCO-IHE.

Chapagain, A.K., Hoekstra, A.Y, and Savenije H. H. G. (2006) Water saving through international trade of agricultural products. Hydrol. Earth Syst. Sci., 10: 455-468 pp.

Caputo, A.C., Scacchia, F., Pelagagge, P.M. 2.3. Disposal of by-products in olive oil industry: waste-to-energy solutions. Applied Thermal Engineering 23: 197-214.

CHG (2007) Special Plan of Actions in Alert and Temporary Drought in the Guadalquivir Basin. Ministerio de Medio Ambiente, y Medio Rural y Marino. Secretaría General de Medio Rural. Available from: http://-www.chguadalquivir.es/opencms/portalchg/index.html [Accessed on June 2010].

Connell, J.H. and Catlin, P.B. (1994) Root physiology and rootstock characteristics. In: Sibbett, G.S. and Ferguson, L. (editors) Olive production manual. University of California, Division of Agriculture and Natural Resources, Publication 3353. Berkley, California, pp: 43-50.

Corominas, J. (2010). Consejería de Agricultura y Pesca. Junta de Andalucía. (Personal communication).

Dietzenbacher, E. and Velázquez, E. (2007) Analysing Andalusian Virtual Water Trade in an Input-Output Framework. Regional Studies, 41(2): 185-196 pp.

Doorenbos, J. and Kassam, A.H. (1979) Yield response to water. Estudio de Riego y Drenaje No. 33, Organización de las Naciones Unidades para la Agricultura y la Alimentación, Roma, 193 pp.

European Comission (2002) Aplicación de la Directiva 91/676/CEE del Consejo relativa a la protección de las aguas contra la contaminación producida por nitratos utilizados en la agricultura. Síntesis de los informes de los Estados miembros del año 2000. Comisión Europea, Dirección General de Medio Ambiente. [Online] Available from: http://europa.eu.int. [Accessed on June 2010].

European Commission (2003) European Soil Data Base version V2.0 [Online]
Available from: http://eusoils.jrc.ec.europa.eu/ [Accessed on October 2010].

EEA (2000) Bossard, M., Feranec, J. and Otahel, J. CORINE land cover technical guide -Addendum 2000. European Environmental Agency. Copenhagen.

EEA (2009) CORINE land cover 2000 (CLC2000) seamless vector database. 223: Olive groves. The European Topic Centre on Land Use and Spatial Information. [Online] Available from: http://www.eea.europa.eu/ [Accessed on May 2010].

Ercin, A.E, Aldaya, M.M. and Hoekstra, A.Y. (2009) A pilot in corporate water footprint accounting and impact assessment, 'Value of Water Research Report Series No: 39', UNESCO-IHE, Delft, the Netherlands.

EU (1991) Directive 91/676/EEC of the Council of the European Communities of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources.

EU (2006) Directive2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration.

FAO (2006) Allen, R.G., Pereira, L.S., Raes, D. and Smith, M. Evapotranspiración del cultivo — Guías para la determinación del requerimiento de agua de los cultivos— FAO Riego y Drenaje 56. Organización de la Naciones Unidas para la agricultura y la alimentación. Roma.

FAO (2009) CROPWAT 8.0 model, Food and Agriculture Organization, Rome, Italy. [www.fao.org/nr/water/infores_databases_cropwat.html] [Accessed on January 2010].

FAO/IPTRID/ICID/ODA (2000) Irrigation Guidelines, Land and Water Digital Media Series 12, & FAO, 2000, Handbook on Pressurized Irrigation Techniques.

FAO-UN (2007) Digital Soil Map of the World. [Online] Available from: http://www.fao.org/geonetwork/srv/en/main.home [Accessed on June 2010].

Fernández-Escobar, R. (2007) Fertilization. In: Production techniques in olive growing. International Olive Council. 145-168 pp. [online] Available from: http://www.internationaloliveoil.org/downloads/Projects/Manual/Olivicultura_eng.pdf [Accessed on June 2010].

García-Vila, M., Lorite, I.J., Soriano, M.A. and Fereres, E. (2008) Management trends and responses to water scarcity in an irrigation scheme of Southern Spain. Agricultural Water Management 95: 458-468 pp.

Garrido, A. Llamas, M.R. Varela-Ortega, C. Novo, P. Rodríguez Casado, R. and Aldaya, M.M. (2010) Water Footprint and Virtual Water Trade in Spain. Policy Implications. La Fundación Marcelino Botín-Sanz de Sautuola y López.

Gómez del Campo, M. and Fernández, J.E. (2007) Manejo del riego de olivares en seto a partir de medidas en suelo y planta. Editorial Agrícola Española, S.A., Madrid.

Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M. and Mekonnen, M.M. (2009) Water footprint manual: State of the art 2009, Water Footprint Network, Enschede, the Netherlands.

IDAE (2007) Ahorro, Eficiencia Energética y Fertilización Nitrogenada. Instituto para la Diversificación y Ahorro de la Energía. Madrid.

Islam, M.D., Oki, T., Kanae, S., Hanasaki, N., Agata, Y. and Yoshimura, K. (2007) A grid-based assessment of global water scarcity including virtual water trading. Water Resour. Manage. 21: 19-33 pp.

Israelsen, O.W. and Hansen, V.E. (1965) Principios y aplicaciones del riego. Editorial Reverté S.A. Barcelona-Buenos Aires-México, 396 pp.

Lavee, S. and Wodner, M. (2003) The effect of yield, harvest time and fruit size on the oil content in fruits of irrigated olive trees (Olea europaea), cvs. Barnea and Manzanillo. Scientia Horticulturae 99: 267-277 pp.

Lavee, S. (2007) Biennial bearing in olive (Olea europaea). ANNALES, Ser. hist. nat. 17 (1): 101-112 pp.

López-Piñeiro, Cabrera, D., Albarrán, Á. and Peña, D. (2010) Cumulative and residual effects of de-oiled two-phase olive mill waste application to soil on diuron sorption, leaching, degradation, and persistence, Chemosphere 78: 139-146 pp.

Lorite, I.J., Mateos, L., and Fereres, E. (2004) Evaluating irrigation performance in a Mediterranean environment: I. Model and general assessment of an irrigation scheme. Irrig. Sci. 23: 77-84 pp.

MAPA (2010) Sistema de Información Agroclimática para el Regadío (SIAR) [online] Available from: http://www.mapa.es/siar/ [Accessed on May 2010].

MARM (2007) Informe Nacional sobre el estado de la cuestión de la biodiversidad en el medio agrario. Ministerio de Medio Ambiente, y Medio Rural y Marino. [Online] Available from: http://www.marm.es/ [Accessed on August 2010].

MARM (2008a) Boletines Hidrológicos. Reserva Hidraúlica. Datos de reserva: desglose por embalses [online] Available from: http://www.marm.es/ [Accessed on June 2010].

MARM (2008b) Sistema integrado de información del agua. Descargas. [Online] Available from: http://servicios3.marm.es/siagua/visualizacion/descargas/series.jsp [Accessed on August 2010].

MARM (2008c) Balance del nitrógeno en la Agricultura española (año 2006). Ministerio de Medio Ambiente, y Medio Rural y Marino. Secretaría General de Medio Rural. Dirección General de Recursos Agrícolas y Ganaderos. [Online] http://www.ruena.csic.es/balances.html [Accessed on May 2010].

MARM (2010a) Agricultural and Statistics Yearbooks. Spanish Ministry of Environment, and Rural and Marine Environments. [Online] Available from: http://www.mapa.es/es/estadistica/pags/anuario/introduccion.htm [Accessed on May 2010].

MARM (2010b) Agricultura. El mercado del aceite de oliva. [Online] Available from: http://www.mapa.es/es/agricultura/pags/mercado_aceiteoliva/index.htm [Accessed on June 2010].

Novo P., Garrido, A. and Varela-Ortega, C. (2008) Are virtual water "flows" in Spanish grain trade consistent with relative water scarcity? Ecological Economics 68: 1454-1464 pp.

OOA (2010a) Información del sector. El olivar español. Agencia para el aceite de oliva. [Online] Available from: http://aplicaciones.mapa.es/pwAgenciaAO/General.aao?idioma=ESP&avisosMostrados=NO&control_acceso=S [Accessed on June 2010].

OOA (2010b) Información de mercados. Aceite de oliva. Balance campaña. Agencia para El aceite de oliva. Available from: http://aplicaciones.-mapa.es/pwAgenciaAO/General.aao?idioma=ESP&avisosMostrados=NO&control_acceso=S [Accessed on June 2010].

Orgaz, F., Villalobos, F., Testi, T., Pastor, M., Hidalgo, J.C. and Fereres, E. (2005) Programación de riegos en plantaciones de olivar. Metodología para el cálculo de las necesidades de agua de riego en el olivar regando por goteo. In: Pastor, M. (editor) Cultivo del olivo con riego localizado. Junta de Andalucía, Consejería de Agricultura y Pesca. 83-137 pp.

Pastor, M., Castro, J., Mariscal, M.J., Vega, V., Orgaz, F., Fereres, E., and Hidalgo, J.C. (1999) Respuestas del olivar tradicional a diferentes estrategias y dosis de agua de riego. Invest. Agr.: Prod. Prot. Veg. Vol. 14 (3): 393-404 pp.

Regional Government of Andalusia (2008) Inventario y caracterización de los regadíos de Andalucía 2008 Junta de Andalucía.

Regional Government of Andalusia (2003) Inventario y caracterización de los regadíos de Andalucía: actualización 2002 [Software: 18 files and 33 megabytes]. Servicio de Regadíos e Infraestructuras, Junta de Andalucía. Cádiz: Servicio de Publicaciones y Divulgación.

Regional Government of Andalusia (1999) Inventario y caracterización de los regadíos en Andalucía. Junta de Andalucía. Sevilla.

Rodríguez-Liziana, A, Ordóñez, R., Espejo, A.J. and Giráldez, J.V. (2005) Manejo de suelo en olivar. Implicaciones sobre la pérdida de suelo y agua por escorrentía, contaminación de aguas superficiales. Agricultura: Revista Agropecuaria. ISBN: 0002-1334, 384-391 pp.

Ruíz, R. (2001) Rendimiento graso industrial en aceite. Agricultura, 327-329 pp.

Scheidel, A., Krausmann, F. (2011). Diet, trade and land use: a socio-ecological analysis of the transformation of the olive oil system. Land Use Policy 28: 47–56.

Strosser, P., Roussard, J., Grandmougin, B., Kossida, M., Kyriazopoulou, I., Berbel, J. Kolberg, S., Rodríguez-Díaz, J.A., Montesinos, P. Joyce, J., Dworak, T., Berglund, M. and Laaser C. (2007) EU Final report. Water saving potential (Part 2 - Case studies). Ecologic - Institute for International and European Environmental Policy, Berlin.

Uceda, M. (2009) Composición y calidad de los aceites de oliva vírgenes extra. Influencia de la variedad. In: J. Vilar (Coord.) Algunas contribuciones sobre olivicultura y Elaiotecnia desde la perspectiva de la experiencia. Jaén: GEA Westfalia Separator Andalucía S.L. 175-187 pp.

Van der Leeden, F., Troise, F.L. and Todd, D.K. (1990) The Water Encyclopaedia - Second edition, Lewis Publishers.

Wichelns, D. (2010) Virtual Water: A Helpful Perspective, but not a Sufficient Policy Criterion. Water Resour. Manage. 24: 2203-2219 pp.

Appendix 1. *Crop parameters*

Rainfed olive orchards

	Initial	*Development*	*Mid-season*	*Late season*	*Total*
Long period (days)	60	95	150	60	365
[1] Crop coefficient (K_c)	0.82		0.44	0.89	
[2] Yield response	0.85				
[3] Rooting depth (m)	0.6				
[4] Critical depletion	0.8		0.7	0.8	
Cropheight (m)	3				
Planting date	01/01				

[1] Source: Orgaz *et al.* (2005) considering 100 trees/ha density of plantation. Factor that includes evaporation from drip irrigators has been subtracted. Mid-season K_c is calculated as the mean over the 150 days period.

[2] Source: Lorite *et al.* (2004).

[3] Connell and Catlin (1994).

[4] If ET_c <5mm/day, critical depletion=0.65+0.04x(5-Etc) (FAO, 2006). It is assumed Et_c = 1mm/day for initial and late season and ET_c = 4 mm/day over mid-season.

Irrigated olive orchards

	Initial	*Development*	*Mid-season*	*Late season*	*Total*
Long period (days)	60	95	150	60	365
[1] Crop coefficient (K_c)	0.85		0.54	0.98	
[2] Yield response	0.85				
[3] Rooting depth (m)	0.6				
[4] Critical depletion	0.8		0.7	0.8	
Cropheight (m)	3				
Planting date	01/01				

[1] Source: Orgaz *et al.* (2005) considering 200 trees/ha density of plantation and 9.000 volume crown. Mid-season K_c is calculated as the mean over this period.

[2] Source: Lorite *et al.* (2004).

[3] Connell and Catlin (1994).

[4] If ET_c <5mm/day, critical depletion=0.65+0.04x(5-Etc) (FAO, 2006). It is assumed Et_c = 1mm/day for initial and late season and ET_c = 4 mm/day over mid-season.

Appendix 2. *Area and crop yield for rainfed and irrigated olive trees for olive oil*

	1997				*1998*				*1999*		
	Area (ha)		*Yield (kg/ha)*		*Area (ha)*		*Yield (kg/ha)*		*Area (ha)*		
	Rainfed	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*
Álava	82		5,402		87		2,356		87		2,920
Albacete	21,000	3,300	1,240	2,771	21,592	3,660	251	2,180	22,900	3,685	538
Alicante	24,819	4,815	1,250	2,270	26,916	2,945	800	2,000	27,372	2,479	725
Almería	7,790	7,188	800	3,250	7,790	7,544	550	2,500	3,500	7,899	150
Ávila	4,250		1,748		4,250		361		4,250		1,919
Baleares	6,867		200		6,867		70		6,867		68
Badajoz	158,538	300	1,300	3,002	159,188	421	962	3,810	146,500	500	979
Barcelona	1,382		1,035		1,358	13	953	1,753	1,361	18	1,285
Castellón	31,294	583	1,496	1,980	32,012	603	655	880	32,132	635	1,235
Ciudad Real	92,648	635	1,805	2,852	92,495	640	599	1,468	92,875	665	861
Cuenca	34,090		650		33,375		564		31,090		666
Cáceres	51,333		1,500		51,400		515		49,000		1,533
Cádiz	14,800	114	1,019	1,365	14,852	206	2,127	2,941	16,503	298	750
Córdoba	297,795	8,761	3,200	4,180	308,318	11,628	2,750	4,615	305,082	14,811	1,440
Girona	1,753	2	1,800	2,300	2,391		1,712		2,370	8	1,800
Granada	113,700	25,505	3,020	4,660	117,200	2,674	900	3,050	117,200	28,154	881
Guadalajara	19,030		505		19,553		665		19,553		459
Guipúzcoa											
Huelva	21,701	19	700	1,600	20,841	20	420	1,000	19,858	275	830
Huesca	9,122	1,092	593	1,985	8,442	2,022	430	1,037	7,649	1,882	437
Jaén	419,313	154,446	3,985	4,620	422,101	161,439	2,826	4,480	421,953	109,135	1,416
La Rioja	1,817	323	1,206	1,304	1,862	346	1,276	1,396	1,915	365	1,195
Las Palmas											
Lleida	34,643	1,103	1,737	2,800	32,608	2,593	671	3,439	32,815	2,868	868
Madrid	22,419		124		21,036	3	574	700	20,694	3	1,153
Málaga	103,141	4,228	3,800	5,800	104,680	4,739	1,725	3,800	104,800	5,263	1,982
Navarra	1,573	914	2,305	2,607	1,594	944	2,476	3,067	1,567	1,129	1,865
Murcia	13,601	2,752	1,168	2,531	13,628	2,790	982	1,608	14,941	2,953	800
Salamanca	3,426	21	1,012	1,429	3,426	21	1,000	1,578	3,426	21	1,200
Sevilla	105,477	9,733	2,909	4,322	105,137	14,248	2,868	3,985	87,582	7,804	1,857
Tarragona	65,018	5,623	1,949	3,509	67,852	6,035	831	2,911	69,951	5,530	1,795
Teruel	28,068	1,436	896	1,809	28,068	1,436	490	1,015	28,051	1,443	700
Toledo	96,809	154	1,906	3,788	98,685	203	833	3,253	98,581	328	1,530
Valencia	26,056	1,510	1,698	2,000	26,136	1,610	750	2,000	26,203	1,728	1,300
Valladolid											
Zamora	60		3,603		45		2,242		45		2,242
Zaragoza	11,678	5,419	900	1,280	12,567	5,613	465	1,785	9,786	5,610	550

production (I)

		2000				2001				2002		
Yield (kg/ha)		Area (ha)		Yield (kg/ha)		Area (ha)		Yield (kg/ha)		Area (ha)		Yield (kg/ha)
Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
	89		2,135		89		2,135		90		3,094	
2,374	20,940	3,568	518	2,113	21,340	3,743	950	3,760	21,245	4,252	639	2,900
1,500	25,766	6,458	457	1,500	28,319	3,953	888	2,465	28,585	4,035	783	2,450
4,176	3,600	8,255	350	3,800	4,000	8,610	1,200	7,300	4,000	8,966	815	4,890
	4,283		425		4,283		1,771		4,283		1,500	
	6,867		53		6,867		53		6,867		78	
5,000	146,500	500	936	5,000	145,000	500	1,533	5,000	145,000	1,000	1,124	5,000
2,460	1,371	21	920	2,096	1,421	47	1,251	2,413	1,458	57	1,019	2,073
1,554	32,492	666	685	950	32,527	605	1,420	2,100	32,363	675	785	990
2,163	92,903	682	1,250	2,360	93,168	731	1,738	2,355	95,097	832	925	2,850
	31,513	1,214	479	725	32,273	1,220	1,108	1,200	32,873	1,220	680	1,320
	55,000		490		50,000		1,080		50,200		825	
2,100	17,300	391	1,300	3,600	17,500	483	1,300	3,600	18,100	575	1,250	3,500
4,600	305,763	17,716	3,095	4,500	310,832	20,537	4,090	5,677	315,377	23,462	2,387	4,225
2,000	2,439	8	1,350	3,000	2,523	18	1,200	5,333	2,571	21	1,900	6,000
2,706	117,200	29,467	2,134	3,301	121,989	30,802	2,535	4,609	124,118	32,131	1,710	3,076
	19,553		415		19,553		467		15,346		991	
1,200	19,587	410	610	1,100	19,054	590	820	1,200	19,075	623	880	1,200
2,676	8,942	1,876	260	1,924	9,039	2,002	1,077	3,559	8,945	2,431	68	101
3,338	424,240	165,285	3,755	4,455	425,718	168,779	4,325	5,135	426,302	172,252	2,300	4,465
1,452	1,938	492	590	1,966	1,931	535	983	2,230	1,851	575	542	1,825
										2		3,500
3,500	34,368	3,273	552	2,700	33,508	3,356	1,226	2,796	33,392	3,823	203	370
1,200	20,806	3	480	1,200	22,415	285	600	1,200	24,009	395	750	1,200
5,225	104,800	5,751	2,245	6,250	105,480	6,187	3,555	5,700	105,850	6,798	1,700	2,600
3,584	1,568	1,136	1,903	1,406	2,741	1,441	1,514	2,777	2,771	1,671	1,065	1,679
1,358	14,272	2,578	855	1,458	11,849	4,182	1,142	1,894	12,406	5,124	1,100	1,900
1,600	1,872	21	596	1,200	2,160	11	950	1,800	2,287	2	708	1,200
4,241	79,431	9,174	2,267	3,775	103,395	13,065	3,050	4,875	99,320	11,567	1,525	2,975
4,443	69,533	7,835	561	2,098	68,227	8,703	1,730	4,652	70,815	8,792	726	1,274
1,199	28,072	1,555	236	561	25,890	1,322	1,467	2,500	23,286	1,587	526	1,812
3,128	100,490	713	636	3,319	101,516	1,015	1,423	3,305	107,151	1,709	1,423	3,305
3,400	26,272	1,815	525	3,000	26,327	2,231	1,460	3,000	18,977	1,724	1,100	3,020
									1		1,000	
					51		8,625		52		7,885	
1,650	9,901	5,650	300	800	10,435	6,112	900	1,900	10,193	6,358	1,346	2,000

Appendix 2. *Area and crop yield for rainfed and irrigated olive trees for olive oil*

	2003				*2004*				*2005*		
	Area (ha)		*Yield (kg/ha)*		*Area (ha)*		*Yield (kg/ha)*		*Area (ha)*		
	Rainfed	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*
Álava	90		7,133		90		3,250		90		2,750
Albacete	21,500	4,300	1,250	3,600	21,500	4,300	585	2,261	21,300	4,500	565
Alicante	28,639	4,046	805	2,450	28,640	4,046	400	1,180	28,467	4,053	1,175
Almería	5,925	9,841	1,020	4,890	4,500	10,667	334	2,573	4,515	11,541	1,250
Ávila	3,544	10	3,200	4,500	3,545	10	1,650	3,250	3,545	10	2,700
Baleares	6,867		78		7,838	109	168	2,248	7,838	184	252
Badajoz	145,000	1,000	1,402	5,000	145,000	1,500	1,489	5,000	142,800	3,000	1,147
Barcelona	1,510	70	1,335	3,450	1,534	78	1,404	3,489	1,629	88	1,073
Castellón	32,390	670	1,045	1,550	32,820	695	740	1,400	32,998	694	1,020
C. Real	118,106	1,368	1,742	4,510	131,582	4,971	930	2,065	131,582	4,971	600
Cuenca	33,450	1,220	1,225	2,541	33,750	1,220	495	1,200	36,850	1,477	447
Cáceres	50,200		1,237		50,200		1,179		50,500		1,031
Cádiz	18,100	793	1,600	4,500	17,650	1,011	1,375	4,500	18,000	1,229	1,280
Córdoba	316,236	27,199	4,389	6,556	318,659	31,023	2,990	4,969	319,331	34,904	2,255
Girona	2,654	80	860	1,900	2,446	121	900	2,072	2,584	114	900
Granada	126,334	36,957	2,760	4,257	129,474	42,041	1,670	2,935	129,474	47,097	1,098
Guadalajara	15,436		955		16,297		526		16,297		350
Guipúzcoa											
Huelva	18,965	1,106	955	1,350	20,623	1,610	1,150	1,975	20,938	1,964	1,066
Huesca	8,221	2,380	655	330	6,556	2,157	525	940	6,556	2,157	320
Jaén	389,503	186,631	4,400	6,958	386,147	202,012	2,710	4,871	385,369	217,553	1,260
La Rioja	1,937	584	2,530	4,029	1,948	765	884	2,942	2,089	992	612
Las Palmas		3		3,500		3		4,000		8	
Lleida	33,702	3,823	292	587	34,864	3,765	579	994	34,990	2,536	154
Madrid	24,904	396	1,000	2,500	25,584	392	315	1,650	25,212	392	640
Málaga	105,226	9,433	3,600	4,600	105,614	11,834	1,950	4,607	108,623	14,290	2,139
Navarra	2,718	1,523	2,212	3,384	2,891	1,571	2,024	3,479	2,839	1,694	986
Murcia	12,688	5,337	1,200	1,950	12,579	5,500	640	1,800	12,673	5,735	625
Salamanca	2,322		1,034		2,312		870		2,310		654
Sevilla	94,852	14,247	3,512	4,750	97,611	12,607	2,785	3,925	99,005	19,240	2,169
Tarragona	70,129	7,050	1,517	2,563	69,048	7,434	1,041	2,246	68,773	7,721	1,253
Teruel	23,298	1,660	1,591	4,086	25,555	1,310	450	650	21,500	1,638	960
Toledo	112,794	1,836	1,466	3,455	112,776	1,934	690	2,113	113,399	2,580	1,110
Valencia	20,069	1,867	2,250	4,255	20,084	2,266	722	1,500	29,594	3,036	1,220
Valladolid	1	120	700	1,000	54	146	800	1,400	23	263	400
Zamora	51		8,040		51		1,200		52		577
Zaragoza	9,441	6,467	1,000	2,000	9,068	6,120	1,000	1,890	8,375	5,542	900

production (II)

		2006				2007				2008		
Yield (kg/ha)		*Area (ha)*		*Yield (kg/ha)*		*Area (ha)*		*Yield (kg/ha)*		*Area (ha)*	*Yield (kg/ha)*	
Irrigated	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*
	180		3,325		183		1,935		183		1,995	
2,550	21,400	4,800	460	2,025	21,667	4,900	1,300	2,900	27,552	5,796	1,000	2,215
2,730	27,267	4,260	650	2,250	25,696	4,270	1,010	2,820	24,881	4,283	790	2,700
3,989	4,553	12,412	484	2,779	4,953	13,288	1,041	3,001	6,228	14,157	1,054	2,908
3,500	3,344	10	3,000	4,500	3,344	10	3,000	4,500	3,493	10	2,800	4,500
2,112	7,838	184	252	2,112	7,838	184	141	1,600	7,838	184	160	2,060
5,000	142,800	3,500	1,465	5,000	142,800	3,500	1,166	5,000	142,700	6,500	1,142	4,954
1,981	2,480	63	1,121	2,143	2,619	75	960	2,507	2,560	99	1,298	3,310
2,000	32,524	1,075	810	2,000	30,667	1,398	1,215	3,000	32,468	1,466	1,200	2,800
900	131,044	4,985	600	1,350	131,044	4,985	765	1,575	125,356	5,250	1,695	5,223
1,206	37,409	1,506	560	1,190	37,409	1,482	858	2,488	32,817	1,482	479	1,400
	50,500		1,517	5,000	50,500		745		51,400		712	
3,850	19,036	1,447	1,400	3,900	16,608	1,639	1,500	3,800	18,271	1,502	1,700	3,710
5,305	319,547	38,759	3,380	5,336	312,930	42,274	3,762	5,402	323,432	46,572	2,930	5,062
2,000	2,968	10	900	2,000	2,463	180	900	2,000	3,284	233	722	1,838
2,426	132,850	51,950	1,195	3,078	135,168	56,698	1,936	3,048	135,678	61,543	1,192	3,898
	16,297		540		20,338	414	590	750	19,441	338	350	450
	2		1,000		2		1,000		9		950	
2,380	21,266	2,404	1,100	2,150	20,809	2,576	1,050	1,900	24,167	3,503	1,075	1,900
1,062	6,634	2,204	784	2,100	6,760	2,429	830	2,100	6,697	2,403	600	1,850
3,313	386,444	232,941	3,210	5,545	384,247	248,363	2,965	6,147	387,631	263,807	2,910	4,742
2,779	1,989	1,265	1,063	3,410	2,023	1,332	870	3,450	2,842	2,244	1,531	2,878
4,700		12		3,187		18		2,000		34		2,000
1,114	36,331	4,806	770	1,634	36,591	4,935	446	1,295	36,696	5,536	567	1,924
2,000	17,803	392	499	2,000	15,992	392	1,452	2,959	25,210	146	1,381	2,500
5,000	111,760	16,557	2,100	4,500	111,919	18,951	2,800	4,650	109,902	21,164	1,950	5,000
2,873	3,088	2,133	2,702	3,404	3,110	2,148	1,967	2,590	3,210	2,430	2,268	2,932
1,768	12,707	5,955	830	1,950	12,972	6,065	800	1,555	14,233	7,794	850	1,700
	2,301		1,738		2,127		400		2,136		825	
3,979	97,742	22,307	2,844	4,831	101,409	24,820	3,182	3,819	109,250	30,849	3,210	4,174
2,819	68,124	7,845	477	3,778	63,321	9,904	836	2,394	62,579	11,805	1,376	4,318
1,730	21,522	1,733	691	1,617	21,644	1,738	839	2,100	22,052	1,813	470	2,200
2,328	112,100	3,855	800	2,559	111,817	3,995	1,605	4,548	111,963	4,286	928	4,551
2,000	28,555	3,072	949	1,995	28,562	3,484	1,030	4,043	27,612	4,015	1,000	3,750
500	268	82	850	4,925	398	162	750	3,800	645	333	1,300	2,500
	298		2,350		298		670		304		1,678	
1,700	8,322	5,660	1,017	2,200	7,949	6,148	900	2,000	7,937	7,018	700	2,000

Appendix 2. *Area and crop yield for rainfed and irrigated olive trees for olive table*

	1997				1998				1999		
	Area (ha)		*Yield (kg/ha)*		*Area (ha)*		*Yield (kg/ha)*		*Area (ha)*		
	Rainfed	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*
Albacete	75	30	1,440	3,100	92	25	350	2,600	250	165	590
Alicante	1,077	518	920	1,600	970	402	600	1,250	979	178	1,000
Almería											
Ávila	38		1,750		38		370		38		1,870
Baleares	1,306		100		1,306		37		1,306		35
Badajoz	15,462	700	1,610	3,009	15,812	856	1,300	4,000	28,500	1,000	1,722
Barcelona											
Castellón	125		1,475		125		690		123		1,200
Cuenca	21		790		21		700		21		700
Cáceres	23,467	700	1,615	3,001	23,600	720	711	4,000	26,000	800	1,900
Cádiz											
Córdoba	1,921	989	5,100	5,864	2,079	1,146	4,000	6,579	1,973	986	2,300
Girona	5		1,800		4		2,000		43	2	2,000
Granada	50	375	2,900	4,200	50	37	840	1,367	50	389	840
Guadalajara	100		600		90		700		90		600
Huelva	4,241	853	900	2,500	4,215	916	800	1,800	3,704	725	1,100
Jaén	75	1,667	2,300	4,000	75	1,664	2,000	3,700	75	1,130	1,200
Las Palmas	6	4	500	3,000					1		1,000
Lleida	83		1,759		83		675		91		800
Madrid	119		126		115		600		115	2	1,153
Málaga	3,998	459	1,850	3,400	3,998	480	1,600	3,400	3,998	488	1,850
Navarra									6		1,650
Murcia	352	512	1,205	2,272	352	586	995	1,344	357	642	805
Salamanca	1,170	28	1,000	1,487	1,170	28	1,000	1,487	1,170	28	1,300
Sevilla	45,117	15,857	2,566	3,614	44,456	12,884	2,807	3,898	64,312	20,869	2,493
Tarragona		67		2,537		114		7,386		104	
Toledo	4		2,250								
Valencia	92		1,698		92		1,009		92		900
Zaragoza	543	276	650	950	790	278	450	951	611	208	650

production (I)

		2000				2001				2002		
Yield (kg/ha)		*Area (ha)*		*Yield (kg/ha)*		*Area (ha)*		*Yield (kg/ha)*		*Area (ha)*	*Yield (kg/ha)*	
Irrigated	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*
2,960	650	275	640	2,500	250	100	955	3,780	250	125	600	4,000
1,500	146	156	900	1,500	136	162	1,500	2,506	123	137	1,350	2,450
	5		375		5		1,500		5		1,200	
	1,306		33		1,306		33		1,306		33	
5,007	28,500	1,000	1,769	5,000	35,000	1,000	1,914	5,000	35,000	1,000	1,371	5,000
	83		690		93	4	1,420	2,100	92		770	
		32		725		32		1,200		32		1,200
4,000	20,000	800	340	4,000	25,000	800	1,232	4,000	25,000	800	1,484	5,000
5,800	2,034	1,105	3,200	5,000	2,044	1,307	3,850	5,500	2,104	1,406	3,942	6,100
3,500	16	2	1,688	3,000	7	2	1,714	2,500	7	2	1,900	4,000
3,600	50	407	1,200	3,500	50	404	1,900	4,000	50	406	500	3,500
	90		600		90		600		90		550	
1,700	4,439	653	750	1,500	4,077	537	900	1,960	4,077	568	825	1,775
3,000	35	1,313	3,500	4,000	225	1,314	3,800	4,500	225	1,336	2,090	3,065
	4	2	1,000	3,500	4	3	1,000	2,333	2	4	1,000	3,500
	95		620		95		632		102		196	
1,200	164	2	850	1,200	103	9	600	1,200	103		750	
4,500	3,998	533	2,025	5,150	3,998	629	2,600	5,000	3,998	550	2,400	4,600
	6		1,650									
1,225	692	832	793	1,225	588	873	915	1,556	566	547	1,000	1,600
1,500	600	28	800	1,200	673	7	1,500	2,200	696	4	1,190	1,500
3,920	67,325	21,041	2,134	3,156	46,438	18,691	4,104	5,068	45,274	21,731	2,100	4,050
7,981	94	88	840	2,057	94	89	1,457	4,124	102	66	1,303	4,091
	82		500		70		1,300		70		1,000	
1,749	85	373	400	1,000	60	81	900	1,900	60	81	1,346	2,000

Appendix 2. *Area and crop yield for rainfed and irrigated olive trees for olive table*

	2003				*2004*				*2005*		
	Area (ha)		*Yield (kg/ha)*		*Area (ha)*		*Yield (kg/ha)*		*Area (ha)*		
	Rainfed	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*
Albacete	250	150	800	4,000	200	125	350	2,200	175	150	400
Alicante	123	137	1,200	2,500	123	137	580	1,210	122	150	1,050
Almería					25	48	200	2,947	25	49	360
Ávila					12		1,100				
Baleares	1,306		34		79		167		79		165
Badajoz	35,000	1,000	1,766	5,000	35,000	1,000	1,682	5,000	34,700	1,000	925
Barcelona											
Castellón	76	4	1,045	1,550	71	4	740	1,400	24		1,020
Cuenca		32		1,200		32		1,450		32	
Cáceres	25,000	800	1,512	5,000	25,000	800	1,286	5,000	25,000	800	708
Cádiz											
Córdoba	2,140	1,795	4,450	6,900	2,115	2,097	3,850	5,580	2,125	2,342	3,100
Girona		7		4,000		2		2,500			
Granada	50	433	1,066	3,777	20	203	1,571	2,136			
Guadalajara	60		750		60		526		21		350
Huelva	5,866	739	1,000	2,000	4,275	889	1,000	2,000	4,000	1,189	500
Jaén	195	2,533	3,390	4,995	195	2,728	2,310	3,740	2	2,763	1,400
Las Palmas		9		4,000		7		4,143	4	21	3,500
Lleida	102		275		102		431		102		392
Madrid	114		1,000	2,500	111		400		111		640
Málaga	5,940	425	3,600	5,000	5,933	533	2,139	5,005	5,975	587	2,139
Navarra											
Murcia	448	720	1,050	1,650	450	724	525	1,450	450	768	425
Salamanca	714		1,470		714		950		726		702
Sevilla	42,581	27,744	3,345	5,300	43,591	38,077	2,675	4,775	43,309	40,137	2,405
Tarragona	45	36	1,200	4,556	10	27	1,000	3,556	34	12	2,000
Toledo											
Valencia	70	1	2,250	2,500	70		700		70		1,300
Zaragoza					68	86	1,800	6,000	23	422	500

production (II)

		2006				2007				2008		
Yield (kg/ha)		*Area (ha)*		*Yield (kg/ha)*		*Area (ha)*		*Yield (kg/ha)*		*Area (ha)*	*Yield (kg/ha)*	
Irrigated	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*	*Rainfed*	*Irrigated*
2,400	175	150	320	1,920	150	200	320	1,920	130	210	500	2,200
2,700	75	119	800	2,400	75	119	1,050	2,800	75	119	900	2,800
3,854	27	52	296	2,360	27	51	815	2,460	27	56	815	5,160
	79		165		79		165		79		165	
5,000	34,700	1,100	1,644	5,000	34,700	1,100	1,715	5,000	34,100	1,900	1,490	4,838
									1		700	
2,000	24		900		24		1,300		27		1,275	
1,150		32		1,150		32		1,200		32		1,100
5,000	25,000	800	1,653	5,000	25,000	800	922	3,800	25,000	800	874	3,790
					115	26	1,500	3,800	469	381	1,700	3,700
5,500	2,152	2,612	3,330	4,999	2,228	3,223	3,771	5,000	2,491	3,051	3,058	5,075
	1		1,000		2		1,000		7		667	
					100	106	1,965	3,841	100	114	1,851	2,860
	11		540									
1,800	3,980	1,402	600	1,900	5,371	1,884	620	1,950	3,882	1,611	500	1,900
2,700	2	2,950	1,450	2,700	2	3,104	1,600	3,620	2	3,236	1,675	3,950
4,900	4	20	1,100	2,200	4	20	1,100	1,930	5	18	1,000	2,000
	102		441		29		414		1		600	
	111		640		111		1,600		111		1,981	
5,000	6,487	829	1,875	4,500	6,285	945	3,800	5,000	4,975	1,241	1,950	5,000
1,350	455	773	450	1,550	468	680	476	1,580	468	730	650	1,800
	758		2,506		931		617		978		587	
4,689	45,402	45,763	2,464	3,582	44,383	51,943	2,981	4,102	46,647	54,607	2,856	3,693
4,333	8	3	1,750	4,000	25	5	1,760	4,000	1	3	1,980	5,600
	68		949		68		1,030		57		1,000	
1,500	20	400	900	1,500	1	3	900	2,000				

Appendix 3. *The water footprint of olive orchards in m^3/ton for each province over*

	1997				1998				1999		
	[1]WF green (r)	[2]WF green (i)	[3]WF blue	[4]WF grey	WF green (r)	WF green (i)	WF blue	WF grey	WF green (r)	WF green (i)	WF blue
Álava	850				1,875				1,512		
Albacete	3,753	1,740	771	1,277	13,496	1,537	980	3,480	5,145	1,144	892
Alicante	1,957	263	971		1,919	840	1,120		3,099	1,441	1,427
Almería	2,865	749	658	1,143	1,857	434	856	1,496	15,641	527	512
Ávila	2,284				11,268				1,463		
Baleares	25,929			3,466	67,677			9,853	52,995		
Badajoz	3,122	1,303	712		3,900	801	544		2,842	562	428
Barcelona	3,706			1,224	5,280	2,343	1,221	1,319	3,776	1,642	870
Castellón	2,294	1,731	1,081	153	4,015	3,097	2,432	349	2,666	1,990	1,377
Ciudad Real	2,231	1,330	750	694	6,411	2,462	1,458	2,079	3,019	962	989
Cuenca	6,610				7,139				5,269		
Cáceres	3,155	1,520	713		7,677	1,056	535		2,040	777	535
Cádiz	4,333	2,550	1,568	1,829	1,953	1,275	728	874	5,128	1,417	1,019
Córdoba	1,376	952	492		1,653	903	447		2,532	589	458
Girona	2,414	1,226	930	1,441	2,433			1,515	2,164	1,230	930
Granada	1,375	807	460	536	3,451	990	707	1,878	2,421	640	787
Guadalajara	8,960				6,453				8,642		
Guipúzcoa											
Huelva	5,839	1,614	863	897	6,810	1,930	1,200	1,335	4,610	2,186	1,370
Huesca	8,577	1,844	1,078	2,006	8,029	3,023	2,064	2,719	9,252	1,361	800
Jaén	1,028	854	464		1,392	876	479		2,313	822	642
La Rioja	3,964	2,538	1,641	232	2,623	2,329	1,533	219	3,280	2,204	1,474
Las Palmas	1,958	327	713	2,834					1,221		
Lleida	2,657	1,577	764	1,797	3,958	762	622	3,636	4,811	1,070	611
Madrid	29,754			10,928	7,246	5,897	3,057	2,360	2,338	1,975	1,783
Málaga	1,149	690	385		1,871	854	569		1,726	638	414
Navarra	1,950	1,143	821		1,768	965	698		2,303	773	597
Murcia	2,410	1,162	859		2,490	1,734	1,370		3,095	1,561	1,604
Salamanca	3,213	2,101	1,464		3,797	2,236	1,402		2,348	1,595	1,387
Sevilla	1,172	794	551		1,494	1,069	543		1,549	635	534
Tarragona	2,131	1,104	612	560	4,673	1,191	715	1,148	2,216	750	475
Teruel	5,356	2,289	1,183	1,064	7,440	3,557	2,108	1,941	5,339	2,719	1,785
Toledo	1,916	771	565	547	5,326	1,030	658	1,247	1,747	620	684
Valencia	1,815	1,670	1,070	677	4,092	1,540	1,070	1,410	2,909	1,118	629
Valladolid											
Zamora	1,118				1,623				1,303		
Zaragoza	5,494	3,612	1,693	3,321	4,446	1,157	1,226	3,910	5,656	1,905	1,294

[1] WF green (r) = Green water footprint (rainfed) in m^3/ton. [2] WF green (i) = Green water footprint (irrigated) in m^3/ton.

the period 1997-2008 (I)

		2000				2001				2002		
WF grey	*WF green (r)*	*WF green (i)*	*WF blue*	*WF grey*	*WF green (r)*	*WF green (i)*	*WF blue*	*WF grey*	*WF green (r)*	*WF green (i)*	*WF blue*	*WF grey*
	2,418				2,053				1,570			
2,303	3,795	886	701	2,416	2,715	641	569	1,347	6,030	1,371	730	1,803
	4,912	1,675	1,000		3,758	1,131	868		4,003	1,360	873	
768	6,794	589	395	821	1,287	205	293	421	2,276	378	438	622
	8,780				2,256				2,266			
10,167	80,541			12,805	89,075			12,805	95,381			9,006
	3,799	693	300		2,414	699	428		3,154	696	428	
974	4,210	1,756	716	1,351	3,578	1,528	887	983	5,679	2,074	1,032	1,196
186	5,806	4,008	1,579	334	2,416	1,353	1,019	161	6,322	5,090	2,162	292
1,445	2,853	1,334	636	1,000	2,241	1,479	909	722	3,606	1,106	751	1,336
	7,397	4,211	2,069		4,077	3,143	1,783		7,089	3,324	1,625	
	8,230	821	375		3,559	903	535		3,681	698	428	
2,415	3,451	1,001	417	1,384	3,314	1,030	594	1,372	3,250	1,211	611	1,417
	1,395	839	331		1,040	687	378		2,002	984	494	
1,437	2,588	1,083	500	1,910	3,243	689	424	2,107	2,326	515	367	1,341
1,435	1,714	1,052	454	751	1,652	816	465	602	2,240	1,197	695	893
	9,124				7,650				4,741			
787	7,365	2,622	1,115	1,064	5,061	2,469	1,370	816	5,209	2,936	1,452	787
1,693	13,513	1,781	780	2,713	4,231	1,201	601	974	56,036	34,327	21,188	19,827
	981	748	337		1,140	885	417		1,607	845	480	
229	6,248	1,823	763	326	3,945	1,593	960	226	7,855	1,737	1,173	335
4,252	1,152	323	429	2,319	926	386	917	2,706	1,894	549	611	1,479
2,947	5,590	1,092	556	4,306	3,214	1,363	765	2,326	17,271	8,936	5,784	14,448
1,175	7,334	2,621	1,250	2,805	5,749	2,613	1,783	2,230	4,617	2,650	1,783	1,790
	1,748	571	244		1,164	654	380		2,473	1,447	778	
	2,663	3,144	1,067		2,749	1,242	771		4,249	1,954	1,275	
	3,255	1,976	1,071		2,490	1,120	1,166		2,889	1,694	1,144	
	4,963	2,567	1,250		3,275	1,663	1,094		4,266	2,221	1,529	
	1,881	1,035	449		1,349	814	429		2,383	1,119	582	
581	7,284	1,747	715	1,615	2,473	795	461	563	6,565	3,351	1,653	1,469
1,382	12,886	5,206	2,674	3,955	1,739	972	856	660	9,316	2,315	1,181	1,646
681	4,846	703	452	1,596	2,545	864	648	725	2,255	775	648	720
812	6,379	1,015	500	1,695	2,473	1,026	713	735	5,515	1,937	709	922
					3,091							
					439				422			
3,525	10,453	3,938	1,846	6,787	3,025	1,408	1,126	2,634	3,331	1,941	1,070	2,095

[3] WF blue (i) = Blue water footprint in in m^3/ton. [4] WF grey = Grey water footprint (rainfed and irrigated) in m^3/ton.

APPENDIX 3. *The water footprint of olive orchards in m^3/ton for each province over*

	2003				2004				2005		
	[1]WF green (r)	[2]WF green (i)	[3]WF blue	[4]WF grey	WF green (r)	WF green (i)	WF blue	WF grey	WF green (r)	WF green (i)	WF blue
Álava	601				1,331				1,451		
Albacete	2,634	851	592	1,124	6,689	1,669	947	2,136	3,849	798	841
Alicante	3,100	1,022	873		7,227	2,432	1,812		1,391	695	784
Almería	1,840	403	438	657	6,537	920	831	1,183	1,161	385	537
Ávila	1,268	783	476		2,193	1,148	658		1,088	753	611
Baleares	63,451			8,986	25,000	1,632	952	3,250	18,301	2,216	1,013
Badajoz	2,327	661	428		2,391	682	428		1,964	395	428
Barcelona	3,198	1,063	620	887	3,374	1,174	613	842	3,745	1,575	1,080
Castellón	5,455	3,092	1,381	218	7,852	3,567	1,529	306	3,174	1,541	1,070
Ciudad Real	1,651	662	475	709	5,417	2,075	1,036	1,295	3,025	2,114	2,378
Cuenca	4,245	1,883	854		9,083	3,279	1,774		7,180	2,432	1,776
Cáceres	2,830	645	428		3,971	883	428		2,339	371	428
Cádiz	3,069	895	476	1,085	3,205	956	476	1,210	2,273	641	556
Córdoba	875	530	325		1,559	849	427		1,478	492	402
Girona	5,065	1,637	1,034	2,889	4,550	1,497	1,029	2,713	3,285	1,270	1,070
Granada	1,262	716	503	574	2,140	1,210	730	899	1,728	818	882
Guadalajara	5,013				10,014				8,017		
Guipúzcoa											5,018
Huelva	4,544	2,457	1,329	701	3,590	2,021	1,079	589	2,708	1,088	990
Huesca	6,773	11,645	6,485	2,557	7,291	3,851	2,277	2,370	7,871	2,118	2,015
Jaén	893	508	309		1,471	820	441		2,168	757	647
La Rioja	1,757	877	531	99	5,264	1,289	727	194	3,994	813	770
Las Palmas		475	552	1,097		307	522	1,037	667	485	442
Lleida	14,757	6,590	3,646	9,877	5,825	3,336	2,153	5,137	13,058	1,504	1,921
Madrid	3,282	1,286	856	1,324	15,619	2,615	1,297	4,040	3,037	805	1,070
Málaga	1,198	806	463		2,163	856	463		1,657	678	428
Navarra	1,692	934	632		1,817	851	615		4,217	1,215	745
Murcia	2,701	1,513	1,118		6,113	2,244	1,216		4,408	1,835	1,245
Salamanca	3,456				3,113				3,144		
Sevilla	1,231	715	419		1,583	922	469		1,278	543	480
Tarragona	3,134	1,682	832	719	4,599	1,855	951	1,001	3,231	1,259	759
Teruel	3,324	1,184	524	570	7,199	4,916	3,292	2,177	2,661	1,292	1,237
Toledo	1,732	591	619	698	6,354	1,587	1,013	1,464	1,395	486	919
Valencia	1,968	988	503	479	7,420	3,042	1,427	1,449	2,499	1,610	1,070
Valladolid	5,900	3,829	2,140		3,930	2,029	1,529		13,688	8,766	4,280
Zamora	435				2,534				3,707		
Zaragoza	4,063	1,773	1,070	2,380	3,310	1,733	1,099	2,415	3,166	1,667	1,269

[1] WF green (r) = Green water footprint (rainfed) in m^3/ton. [2] WF green (i) = Green water footprint (irrigated) in m^3/ton.

the period 1997-2008 (II)

		2006				2007				2008		
WF grey	WF green (r)	WF green (i)	WF blue	WF grey	WF green (r)	WF green (i)	WF blue	WF grey	WF green (r)	WF green (i)	WF blue	WF grey
	1,369				2,809				2,203			
2,020	7,116	1,433	742	2,466	2,939	1,155	524	1,164	4,894	1,838	677	1,524
	4,160	1,064	665		5,533	1,795	532		3,698	830	555	
702	5,953	871	540	1,045	2,700	706	500	916	2,538	701	514	962
	1,249	788	333		1,567	1,034	333		1,425	804	333	
2,174	16,762	1,856	710	2,174	36,297	3,106	938	3,657	20,057	1,141	728	3,138
	2,713	709	300		3,243	795	300		3,865	875	304	
1,131	4,619	2,442	700	1,105	5,983	2,387	598	1,263	3,635	1,382	453	923
221	5,461	2,201	750	272	5,162	2,019	500	178	3,558	1,391	536	181
2,059	6,829	2,477	1,111	2,004	7,422	3,332	952	1,583	3,055	848	287	685
	8,924	3,767	1,261		6,068	2,045	610		11,154	3,228	1,076	
	2,631	773	300		6,586	1,392	395		6,177	1,214	396	
1,294	3,201	1,135	385	1,185	3,314	1,268	395	1,094	2,072	1,261	405	992
	1,413	861	282		1,517	1,007	279		1,943	1,107	296	
2,742	2,709	1,015	750	2,872	4,850	2,130	750	2,662	7,502	2,643	816	3,262
1,226	2,908	1,102	487	1,032	1,505	897	492	786	2,579	705	385	874
	8,906				2,246	1,976	2,000		3,724	299	3,333	
			6,007				4,858					
639	4,671	2,261	729	612	5,114	2,626	781	643	5,527	2,624	789	624
2,954	6,098	2,110	714	1,338	4,793	1,890	714	1,277	7,465	2,221	811	1,600
	1,313	740	272		1,550	684	245		1,793	957	317	
216	4,451	1,296	440	143	5,753	1,342	435	150	3,142	1,406	521	133
908	1,322	564	584	1,766	1,349	749	764	2,260	1,220	605	750	2,223
14,497	3,136	1,301	918	3,655	4,898	1,630	1,158	5,815	6,577	1,810	780	4,269
2,051	7,389	1,588	750	2,547	3,417	1,589	507	910	3,356	1,563	600	975
	1,995	887	333		1,665	1,022	321		2,121	768	300	
	2,026	1,481	441		3,006	2,206	579		2,479	1,780	512	
	4,063	1,569	788		6,105	3,028	963		4,035	1,562	878	
	1,855				9,037				5,152			
	1,881	1,228	376		1,505	1,143	374		1,781	1,346	388	
822	7,968	947	397	1,418	4,224	1,196	626	1,108	3,770	1,006	347	630
987	5,408	2,263	928	1,317	5,418	2,100	714	1,073	8,945	1,818	682	1,664
919	4,175	862	586	1,217	2,953	795	330	612	3,998	602	330	985
898	3,756	1,719	752	1,105	6,738	1,659	371	855	5,387	1,254	400	861
	5,653	860	305		7,463	1,406	395		3,465	1,584	600	
	1,472				7,509				2,292			
2,732	3,388	1,511	696	2,239	5,001	2,138	750	2,426	5,732	1,842	750	2,556

[3] WF blue (i) = Blue water footprint in in m^3/ton. [4] WF grey = Grey water footprint (rainfed and irrigated) in m^3/ton.

Appendix 4. *The water footprint of olive oil in l/l for each province over the*

	1997				1998				1999		
	[1]WF green (r)	[2]WF green (i)	[3]WF blue	[4]WF grey	WF green (r)	WF green (i)	WF blue	WF grey	WF green (r)	WF green (i)	WF blue
Álava	3,981			10	8,782			10	7,083		
Albacete	17,588	8,156	3,618	5,998	63,314	7,208	4,598	16,351	24,122	5,415	4,222
Alicante	9,066	1,197	4,416	10	8,908	3,756	5,012	10	14,705	6,751	6,682
Almería	13,418	3,510	3,084	5,364	8,699	2,033	4,010	7,018	73,259	2,467	2,401
Ávila	10,699			10	52,788			10	6,850		
Baleares	111,742			14,944	293,098			42,680	228,961		
Badajoz	14,931	6,115	3,339	10	18,846	3,877	2,631	10	14,955	2,633	2,005
Barcelona	17,360			5,741	24,731	10,975	5,718	6,185	17,685	7,690	4,075
Castellón	10,746	8,108	5,063	726	18,808	14,505	11,390	1,646	12,486	9,319	6,450
Ciudad Real	10,447	6,229	3,515	3,260	30,029	11,532	6,828	9,747	14,141	4,505	4,634
Cuenca	30,963			10	33,441			10	24,681		
Cáceres	15,132			10	40,263			10	10,347		
Cádiz	20,297	11,942	7,343	8,577	9,146	5,972	3,408	4,103	24,019	6,635	4,773
Córdoba	6,468	4,641	2,398	10	7,767	4,391	2,172	10	11,903	2,804	2,179
Girona	11,309	5,743	4,358	6,760	11,397			7,109	10,157	6,627	5,012
Granada	6,439	3,772	2,151	2,521	16,161	4,603	3,287	8,806	11,340	3,009	3,704
Guadalajara	42,006			10	30,229			10	40,533		
Guipúzcoa											
Huelva	28,626	11,717	6,265	4,745	36,748	16,113	10,023	7,901	22,695	13,329	8,353
Huesca	40,173	8,636	5,050	9,405	37,605	14,158	9,666	12,744	43,332	6,377	3,746
Jaén	4,814	3,993	2,170	10	6,520	4,096	2,238	10	10,833	3,848	3,003
La Rioja	18,568	11,889	7,687	1,097	12,285	10,906	7,180	1,035	15,362	10,322	6,903
Las Palmas											
Lleida	12,444	7,386	3,580	8,425	18,540	3,567	2,915	17,032	22,528	5,010	2,864
Madrid	139,368			51,197	33,946	27,618	14,319	11,067	10,952	9,250	8,353
Málaga	5,276	3,099	1,729	10	8,741	3,963	2,638	10	8,065	2,955	1,919
Navarra	9,132	5,354	3,845	10	8,281	4,520	3,268	10	10,781	3,620	2,797
Murcia	11,297	5,356	3,961	10	11,664	7,889	6,234	10	14,496	7,185	7,381
Salamanca	15,004	10,067	7,014	10	17,784	10,128	6,352	10	11,233	7,202	6,265
Sevilla	5,297	3,341	2,320	10	6,952	4,955	2,516	10	8,309	2,812	2,364
Tarragona	9,981	5,155	2,857	2,631	21,889	5,737	3,444	5,439	10,377	3,564	2,256
Teruel	25,087	10,719	5,541	4,994	34,845	16,659	9,875	9,102	25,005	12,736	8,360
Toledo	8,973	3,613	2,646	2,574	24,943	4,826	3,082	5,851	8,182	2,902	3,205
Valencia	8,502	7,820	5,012	3,179	19,187	7,213	5,012	6,617	13,609	5,237	2,948
Valladolid											
Zamora	5,236			10	7,600			10	6,104		
Zaragoza	25,413	16,706	7,831	15,377	20,782	5,300	5,616	17,982	26,775	8,942	6,075

[1] WF green (r) = Green water footprint (rainfed) in l/l. [2] WF green (i) = Green water footprint (irrigated) in l/l.

period 1997-2008 (I)

		2000				2001				2002		
WF grey	*WF green (r)*	*WF green (i)*	*WF blue*	*WF grey*	*WF green (r)*	*WF green (i)*	*WF blue*	*WF grey*	*WF green (r)*	*WF green (i)*	*WF blue*	*WF grey*
10	11,326			10	9,616			10	7,352			10
10,950	17,901	4,203	3,325	11,567	12,715	3,001	2,666	6,341	28,220	6,490	3,457	8,543
10	23,134	7,844	4,684	10	17,660	5,299	4,067	10	18,809	6,371	4,091	10
3,608	31,820	2,758	1,849	3,853	6,028	961	1,373	1,981	10,659	1,771	2,050	2,921
10	41,119			10	10,563			10	10,610			10
43,935	354,483			56,367	392,039			56,367	405,548			38,304
10	20,371	3,245	1,406	10	11,855	3,273	2,005	10	15,402	3,258	2,005	10
4,572	19,720	8,225	3,352	6,336	16,756	7,155	4,154	4,615	26,600	9,715	4,835	5,613
879	27,195	18,773	7,396	1,572	11,314	6,336	4,773	763	29,609	23,842	10,125	1,376
6,779	13,362	6,247	2,977	4,692	10,496	6,929	4,257	3,390	16,887	5,178	3,517	6,265
10	34,644	19,723	9,691	10	19,094	14,719	8,353	10	33,202	15,532	7,594	10
10	35,402			10	17,453			10	21,819			10
11,320	16,165	4,686	1,952	6,489	15,522	4,822	2,785	6,437	15,223	5,671	2,864	6,644
10	6,535	3,955	1,562	10	4,867	3,213	1,766	10	9,417	4,723	2,373	10
6,760	12,139	5,074	2,342	8,977	15,205	3,056	1,880	9,898	10,893	2,340	1,671	6,297
6,764	8,028	4,932	2,129	3,530	7,737	3,814	2,175	2,833	10,486	5,615	3,259	4,198
10	42,822			10	35,879			10	22,146			10
3,984	35,959	15,024	6,387	5,362	24,114	15,056	8,353	4,001	24,130	16,892	8,353	3,738
7,937	63,288	8,340	3,652	12,715	19,817	5,625	2,817	4,574	262,454	160,774	99,239	92,872
10	4,593	3,498	1,577	10	5,341	4,140	1,952	10	7,525	3,950	2,245	10
1,083	29,262	8,537	3,574	1,538	18,476	7,461	4,495	1,069	36,790	8,135	5,493	1,579
										2,569	2,864	5,699
13,805	26,190	5,113	2,602	20,169	15,035	6,384	3,585	10,889	80,884	41,853	27,090	67,658
5,514	34,559	12,274	5,855	13,230	26,928	12,237	8,353	10,457	21,623	12,412	8,353	8,391
10	8,159	2,635	1,125	10	5,399	3,029	1,759	10	11,758	7,169	3,855	10
10	12,465	14,724	4,997	10	12,877	5,815	3,610	10	19,900	9,150	5,970	10
10	15,194	8,895	4,819	10	11,553	5,085	5,292	10	13,479	7,816	5,276	10
10	25,175	12,021	5,855	10	17,449	8,462	5,569	10	23,156	12,136	8,353	10
10	8,571	4,294	1,861	10	6,997	3,902	2,056	10	12,479	6,480	3,370	10
2,742	34,141	8,182	3,349	7,593	11,580	3,721	2,155	2,647	30,781	15,955	7,868	6,919
6,481	60,354	24,385	12,524	18,534	8,144	4,551	4,010	3,099	43,633	10,844	5,532	7,719
3,198	22,695	3,295	2,117	7,484	11,919	4,046	3,033	3,405	10,561	3,628	3,033	3,380
3,810	29,872	4,755	2,342	7,944	11,579	4,804	3,341	3,448	25,824	9,075	3,319	4,323
									14,479			10
10					2,055			10	1,976			10
16,502	49,097	18,732	8,782	32,566	14,169	6,597	5,276	12,363	15,601	9,090	5,012	9,827

[3] WF blue (i) = Blue water footprint (irrigated) in l/l. Blue [4] WF grey = Grey water footprint (rainfed and irrigated) in l/l.

APPENDIX 4. *The water footprint of olive oil in l/l for each province over the*

	2003				*2004*				*2005*		
	[1]WF green (r)	*[2]WF green (i)*	*[3]WF blue*	*[4]WF grey*	*WF green (r)*	*WF green (i)*	*WF blue*	*WF grey*	*WF green (r)*	*WF green (i)*	*WF blue*
Álava	2,814			10	6,233			10	6,797		
Albacete	12,286	4,002	2,785	5,291	31,213	7,812	4,433	10,041	17,983	3,730	3,931
Alicante	14,549	4,789	4,091	10	33,915	11,401	8,495	10	6,514	3,253	3,672
Almería	8,619	1,888	2,050	3,089	30,548	4,311	3,896	5,552	5,415	1,804	2,513
Ávila	5,940	3,669	2,228	10	10,258	5,377	3,084	10	5,097	3,526	2,864
Baleares	270,394			38,304	117,085	7,645	4,459	15,208	85,421	10,381	4,746
Badajoz	11,447	3,094	2,005	10	11,482	3,193	2,005	10	8,850	1,852	2,005
Barcelona	14,980	4,977	2,906	4,162	15,804	5,499	2,873	3,952	17,542	7,376	5,060
Castellón	25,549	14,483	6,467	1,032	36,777	16,705	7,160	1,441	14,865	7,216	5,012
Ciudad Real	7,734	3,100	2,223	3,331	25,370	9,719	4,854	6,074	14,170	9,900	11,137
Cuenca	19,881	8,698	3,945	10	42,542	15,438	8,353	10	33,631	11,379	8,311
Cáceres	14,234			10	19,161			10	9,818		
Cádiz	14,374	4,193	2,228	5,094	15,012	4,476	2,228	5,678	10,648	3,000	2,604
Córdoba	4,101	2,489	1,529	10	7,315	4,008	2,018	10	6,940	2,312	1,890
Girona	23,722	8,350	5,276	13,660	21,312	7,036	4,838	12,734	15,384	5,948	5,012
Granada	5,910	3,347	2,355	2,700	10,021	5,658	3,415	4,221	8,095	3,831	4,132
Guadalajara	23,461			10	46,901			10	37,550		
Guipúzcoa											
Huelva	21,518	13,729	7,425	3,407	16,439	9,509	5,075	2,753	11,602	4,629	4,212
Huesca	31,723	54,539	30,373	11,984	34,147	18,038	10,663	11,112	36,865	9,919	9,438
Jaén	4,182	2,369	1,441	10	6,887	3,828	2,058	10	10,152	3,536	3,026
La Rioja	8,231	4,106	2,488	471	24,654	6,039	3,407	916	18,708	3,808	3,607
Las Palmas		2,462	2,864	5,699		1,475	2,506	4,988		2,342	2,133
Lleida	69,106	30,865	17,075	46,254	27,261	15,627	10,084	24,052	61,432	7,043	8,998
Madrid	15,374	6,024	4,010	6,211	73,241	12,249	6,075	18,948	14,223	3,770	5,012
Málaga	5,611	3,787	2,179	10	10,184	4,024	2,176	10	7,762	3,175	2,005
Navarra	7,925	4,374	2,962	10	8,511	3,985	2,881	10	19,753	5,689	3,489
Murcia	12,598	6,956	5,140	10	28,454	10,272	5,569	10	20,419	8,355	5,670
Salamanca	17,794			10	14,898			10	14,984		
Sevilla	5,681	3,605	2,111	10	7,326	5,019	2,554	10	6,182	2,850	2,519
Tarragona	14,678	7,911	3,911	3,380	21,541	8,706	4,463	4,702	15,138	5,902	3,556
Teruel	15,567	5,545	2,453	2,678	33,718	23,024	15,421	10,206	12,464	6,051	5,794
Toledo	8,111	2,766	2,901	3,278	29,762	7,431	4,744	6,866	6,533	2,274	4,306
Valencia	9,217	4,628	2,356	2,255	34,748	14,247	6,682	6,795	11,706	7,538	5,012
Valladolid	27,631	17,935	10,023	10	18,409	9,504	7,160	10	64,111	41,056	20,047
Zamora	2,039			10	11,869			10	17,363		
Zaragoza	19,031	8,306	5,012	11,159	15,593	8,362	5,304	11,552	14,810	7,742	5,896

[1] WF green (r) = Green water footprint (rainfed) in l/l. [2] WF green (i) = Green water footprint (irrigated) in l/l.

period 1997-2008 (II)

		2006				2007				2008		
WF grey	*WF green (r)*	*WF green (i)*	*WF blue*	*WF grey*	*WF green (r)*	*WF green (i)*	*WF blue*	*WF grey*	*WF green (r)*	*WF green (i)*	*WF blue*	*WF grey*
10	6,413			10	13,158			10	10,320			10
9,525	33,247	6,699	3,470	11,621	13,696	5,337	2,423	5,445	22,869	8,606	3,172	7,168
10	19,497	4,993	3,123	10	25,918	8,405	2,492	10	17,326	3,890	2,602	10
3,296	27,816	4,078	2,528	4,900	12,631	3,303	2,341	4,294	11,875	3,294	2,416	4,527
10	5,850	3,690	1,562	10	7,340	4,843	1,562	10	6,673	3,768	1,562	10
10,146	78,239	8,692	3,327	10,146	170,293	14,548	4,391	17,130	93,969	5,344	3,411	14,682
10	13,009	3,320	1,406	10	16,590	3,722	1,406	10	19,165	4,074	1,419	10
5,308	21,635	11,438	3,279	5,185	28,024	11,180	2,803	5,924	17,023	6,472	2,123	4,331
1,046	25,580	10,308	3,513	1,281	24,178	9,458	2,342	844	16,665	6,513	2,510	859
9,652	31,984	11,599	5,205	9,398	34,764	15,606	4,461	7,422	14,307	3,970	1,346	3,217
10	41,797	17,631	5,904	10	28,421	9,474	2,824	10	52,241	15,049	5,019	10
10	12,688	3,620	1,406	10	33,271			10	31,086			10
6,070	14,994	5,318	1,802	5,562	15,520	5,939	1,849	5,139	9,703	5,904	1,894	4,734
10	6,615	4,015	1,317	10	7,104	4,691	1,301	10	9,103	5,184	1,388	10
12,852	12,689	4,752	3,513	13,460	22,717	9,976	3,513	12,477	35,132	12,380	3,823	15,281
5,751	13,621	5,160	2,283	4,845	7,051	4,203	2,305	3,692	12,084	3,298	1,803	4,104
10	41,713			10	10,518	9,254	9,368	10	17,442	1,402	15,613	10
	23,503			10	28,135			10	22,753			10
2,825	20,308	10,138	3,268	2,760	21,939	12,437	3,698	2,912	23,972	12,289	3,698	2,823
13,846	28,563	9,882	3,346	6,276	22,448	8,851	3,346	5,988	34,966	10,403	3,798	7,503
10	6,151	3,445	1,267	10	7,261	3,189	1,143	10	8,400	4,473	1,482	10
1,023	20,845	6,068	2,061	682	26,947	6,287	2,037	710	14,714	6,587	2,442	634
4,246		2,131	2,205	6,258		3,443	3,513	9,966		2,834	3,513	9,966
68,053	14,669	6,093	4,300	17,110	22,937	7,633	5,426	27,242	30,805	8,477	3,652	20,003
9,615	34,669	7,436	3,513	11,955	16,015	7,444	2,375	4,275	15,749	7,321	2,811	4,584
10	9,287	4,153	1,562	10	7,947	4,805	1,511	10	9,933	3,595	1,406	10
10	9,490	6,935	2,064	10	14,080	10,334	2,713	10	11,609	8,339	2,397	10
10	18,730	7,174	3,603	10	28,192	14,205	4,518	10	18,756	7,354	4,133	10
10	9,639			10	49,316			10	21,944			10
10	8,438	4,752	1,455	10	6,911	5,623	1,840	10	8,068	5,842	1,684	10
3,861	37,330	4,434	1,860	6,654	19,790	5,601	2,935	5,201	17,659	4,713	1,627	2,958
4,630	25,329	10,599	4,345	6,178	25,377	9,835	3,346	5,035	41,893	8,517	3,194	7,804
4,315	19,554	4,038	2,746	5,712	13,832	3,724	1,545	2,878	18,727	2,821	1,544	4,621
4,214	17,594	8,052	3,522	5,182	31,558	7,770	1,738	4,013	25,231	5,872	1,874	4,038
10	26,478	4,027	1,427	10	34,956	6,587	1,849	10	16,230	7,418	2,811	10
10	6,896			10	35,169			10	10,735			10
12,878	15,863	6,928	3,194	10,493	23,425	10,012	3,513	11,375	26,848	8,628	3,513	11,980

[3] WF blue (i) = Blue water footprint (irrigated) in l/l. Blue [4] WF grey = Grey water footprint (rainfed and irrigated) in l/l.

Appendix 5. *The apparent water productivity (AWP) in €/m³ for each province*

	1997			*1998*			*1999*		
	AWP Rainfed	*AWP Irrigated*	*Blue AWP*	*AWP Rainfed*	*AWP Irrigated*	*Blue AWP*	*AWP Rainfed*	*AWP Irrigated*	*Blue AWP*
Álava	0.46			0.17			0.28		
Albacete	0.12	0.85	0.59	0.03	0.64	0.39	0.09	0.94	0.53
Alicante	0.25	2.40	0.51	0.20	0.81	0.35	0.15	0.66	0.33
Almería	0.15	1.23	0.66	0.18	1.18	0.40	0.03	1.76	0.89
Ávila	0.17			0.03			0.31		
Baleares	0.02			0.00			0.01		
Badajoz	0.14	0.97	0.63	0.09	1.12	0.67	0.15	1.94	1.10
Barcelona	0.13			0.07	0.46	0.30	0.12	0.82	0.53
Castellón	0.18	0.62	0.38	0.08	0.24	0.13	0.16	0.54	0.32
Ciudad Real	0.22	1.04	0.66	0.06	0.42	0.26	0.16	0.97	0.48
Cuenca	0.06			0.05			0.08		
Cáceres	0.13			0.04			0.21		
Cádiz	0.11	0.49	0.31	0.19	0.81	0.51	0.09	0.79	0.46
Córdoba	0.33	1.34	0.88	0.21	1.14	0.76	0.18	1.75	0.99
Girona	0.17	0.79	0.45	0.13			0.20	0.72	0.41
Granada	0.34	1.58	1.01	0.11	0.93	0.54	0.19	1.31	0.59
Guadalajara	0.05			0.05			0.05		
Guipúzcoa									
Huelva	0.07	0.47	0.31	0.05	0.29	0.18	0.09	0.42	0.26
Huesca	0.05	0.62	0.39	0.04	0.27	0.16	0.05	0.90	0.57
Jaén	0.43	1.49	0.96	0.26	1.18	0.77	0.20	1.29	0.73
La Rioja	0.10	0.41	0.25	0.12	0.35	0.21	0.14	0.51	0.31
Las Palmas									
Lleida	0.19	0.98	0.66	0.10	1.13	0.62	0.10	1.23	0.78
Madrid	0.00			0.05	0.19	0.13	0.20	0.51	0.27
Málaga	0.41	1.93	1.24	0.20	1.12	0.67	0.27	1.88	1.14
Navarra	0.23	0.95	0.55	0.20	0.87	0.50	0.20	1.37	0.77
Murcia	0.18	0.89	0.51	0.15	0.49	0.27	0.15	0.60	0.29
Salamanca	0.12	0.45	0.26	0.08	0.37	0.23	0.18	0.59	0.32
Sevilla	0.39	1.50	0.89	0.23	0.96	0.63	0.27	1.74	0.95
Tarragona	0.22	1.22	0.78	0.08	0.81	0.51	0.20	1.54	0.94
Teruel	0.09	0.60	0.40	0.05	0.28	0.18	0.09	0.44	0.27
Toledo	0.23	1.37	0.79	0.07	0.96	0.58	0.27	1.46	0.70
Valencia	0.23	0.64	0.39	0.08	0.52	0.31	0.15	1.09	0.70
Valladolid									
Zamora	0.35			0.19			0.32		
Zaragoza	0.08	0.37	0.25	0.08	0.59	0.29	0.08	0.59	0.35

over the period 1997-2008 (I)

2000			2001			2002		
AWP Rainfed	AWP Irrigated	Blue AWP	AWP Rainfed	AWP Irrigated	Blue AWP	AWP Rainfed	AWP Irrigated	Blue AWP
0.15			0.26			0.23		
0.10	0.98	0.55	0.21	1.93	1.02	0.06	0.79	0.52
0.08	0.61	0.38	0.15	1.15	0.65	0.09	0.70	0.42
0.05	1.56	0.94	0.43	4.56	1.88	0.17	1.89	0.87
0.04			0.24			0.16		
0.00			0.01			0.00		
0.09	1.83	1.28	0.23	2.17	1.34			
0.09	0.75	0.53	0.16	1.01	0.64	0.07	0.55	0.36
0.07	0.34	0.25	0.24	1.00	0.57	0.06	0.25	0.18
0.14	0.90	0.61	0.26	1.03	0.64	0.11	0.85	0.51
0.05	0.27	0.18	0.14	0.49	0.31	0.05	0.33	0.22
0.05			0.15					
0.11	1.31	0.92	0.17	1.53	0.97	0.12	0.92	0.61
0.27	1.56	1.12	0.54	2.29	1.48	0.18	1.09	0.72
0.15	1.12	0.76	0.17	2.28	1.41	0.16	1.84	1.07
0.21	1.16	0.81	0.34	1.91	1.21	0.16	0.83	0.53
0.04			0.07			0.08		
0.05	0.39	0.27	0.11	0.50	0.32	0.07	0.31	0.21
0.03	0.71	0.50	0.13	1.38	0.92	0.01	0.03	0.02
0.39	1.65	1.14	0.49	1.97	1.34	0.23	1.21	0.77
0.06	0.70	0.49	0.14	0.93	0.58	0.05	0.54	0.32
0.07	1.06	0.70	0.18	1.19	0.76	0.02	0.11	0.07
0.05	0.46	0.31	0.10	0.55	0.32	0.08	0.36	0.22
0.22	2.30	1.61	0.49	2.40	1.52	0.15	0.71	0.46
0.14	0.48	0.36	0.21	1.19	0.74	0.09	0.49	0.30
0.12	0.57	0.37	0.23	1.03	0.51	0.13	0.56	0.34
0.07	0.45	0.31	0.15	0.80	0.48	0.08	0.36	0.21
0.21	1.39	0.97	0.39	2.00	1.31	0.14	0.80	0.52
0.05	0.75	0.53	0.23	1.94	1.23	0.06	0.33	0.22
0.03	0.22	0.15	0.33	1.26	0.67	0.04	0.49	0.33
0.08	1.42	0.86	0.23	1.57	0.90	0.17	1.09	0.59
0.06	1.10	0.74	0.22	1.32	0.78	0.07	0.70	0.52
			1.23			0.84		
0.04	0.30	0.20	0.19	0.92	0.51	0.11	0.55	0.36

APPENDIX 5. *The apparent water productivity (AWP) in €/m³ for each province*

	2003			2004			2005		
	AWP Rainfed	AWP Irrigated	Blue AWP	AWP Rainfed	AWP Irrigated	Blue AWP	AWP Rainfed	AWP Irrigated	Blue AWP
Álava	0.66			0.34			0.39		
Albacete	0.17	1.25	0.74	0.07	0.79	0.50	0.16	1.46	0.71
Alicante	0.14	0.92	0.50	0.07	0.45	0.26	0.42	1.60	0.75
Almería	0.24	2.09	1.00	0.07	1.09	0.57	0.52	2.66	1.11
Ávila	0.33	1.39	0.87	0.21	1.10	0.70	0.53	1.71	0.94
Baleares	0.01			0.02	0.77	0.49	0.03	0.85	0.58
Badajoz	0.18	1.66	1.01	0.19	1.80	1.10	0.32	2.90	1.39
Barcelona	0.13	1.10	0.69	0.14	1.17	0.77	0.16	0.92	0.55
Castellón	0.08	0.46	0.31	0.06	0.44	0.31	0.19	0.94	0.56
Ciudad Real	0.27	1.60	0.93	0.09	0.69	0.46	0.20	0.53	0.25
Cuenca	0.10	0.72	0.49	0.05	0.40	0.26	0.08	0.57	0.33
Cáceres	0.14			0.11			0.28		
Cádiz	0.14	1.40	0.91	0.15	1.49	0.99	0.26	2.00	1.07
Córdoba	0.48	2.10	1.30	0.30	1.62	1.07	0.40	2.65	1.46
Girona	0.09	0.63	0.39	0.10	0.77	0.46	0.18	1.01	0.55
Granada	0.35	1.48	0.87	0.22	1.04	0.65	0.34	1.40	0.67
Guadalajara	0.09			0.05			0.07		
Guipúzcoa								0.14	
Huelva	0.09	0.41	0.27	0.13	0.67	0.43	0.24	1.28	0.67
Huesca	0.07	0.11	0.07	0.07	0.33	0.21	0.08	0.58	0.30
Jaén	0.49	2.31	1.43	0.32	1.67	1.09	0.27	1.71	0.92
La Rioja	0.25	1.33	0.83	0.09	1.03	0.66	0.15	1.51	0.78
Las Palmas		0.00	0.00		2.41	0.89		2.51	1.31
Lleida	0.03	0.19	0.12	0.08	0.37	0.22	0.05	0.71	0.31
Madrid	0.13	0.86	0.51	0.03	0.55	0.37	0.20	1.30	0.56
Málaga	0.36	1.47	0.93	0.22	1.59	1.03	0.36	2.28	1.40
Navarra	0.26	1.16	0.69	0.26	1.33	0.77	0.14	1.30	0.81
Murcia	0.16	0.69	0.39	0.08	0.61	0.40	0.14	0.82	0.49
Salamanca	0.11			0.15			0.19		
Sevilla	0.36	1.52	0.96	0.30	1.30	0.86	0.45	2.09	1.11
Tarragona	0.14	0.76	0.51	0.10	0.74	0.49	0.18	1.23	0.77
Teruel	0.13	1.20	0.83	0.07	0.24	0.14	0.22	0.95	0.48
Toledo	0.25	1.46	0.71	0.08	0.77	0.47	0.43	1.88	0.65
Valencia	0.21	1.23	0.81	0.06	0.47	0.32	0.23	0.89	0.54
Valladolid	0.07	0.29	0.18	0.11	0.51	0.29	0.04	0.20	0.13
Zamora	0.90			0.18			0.16		
Zaragoza	0.10	0.64	0.40	0.14	0.68	0.41	0.19	0.83	0.47

over the period 1997-2008 (II)

2006			2007			2008		
AWP Rainfed	*AWP Irrigated*	*Blue AWP*	*AWP Rainfed*	*AWP Irrigated*	*Blue AWP*	*AWP Rainfed*	*AWP Irrigated*	*Blue AWP*
0.58			0.35			0.21		
0.15	2.16	1.42	0.37	3.06	2.10	0.10	0.96	0.70
0.23	2.38	1.46	0.18	2.45	1.89	0.13	1.41	0.84
0.17	3.01	1.86	0.40	3.67	2.15	0.19	1.59	0.91
0.48	2.55	1.79	0.43	2.66	2.01	0.32	1.95	1.38
0.05	1.78	1.28	0.03	1.52	1.17	0.02	1.06	0.65
0.36	4.76	3.35	0.27	4.34	3.15	0.11	2.08	1.55
0.21	1.79	1.39	0.11	1.38	1.10	0.13	1.34	1.01
0.13	1.30	0.97	0.13	1.73	1.39	0.13	1.19	0.86
0.16	1.42	0.98	0.15	1.53	1.19	0.16	2.22	1.66
0.08	0.76	0.57	0.16	2.12	1.63	0.04	0.58	0.43
0.32	4.01	2.89	0.13			0.07		
0.24	2.64	1.97	0.29	3.14	2.39	0.22	1.51	1.14
0.56	3.73	2.81	0.63	4.39	3.44	0.24	1.99	1.57
0.36	2.24	1.29	0.20	1.73	1.28	0.06	0.76	0.58
0.33	2.87	1.99	0.53	2.50	1.61	0.18	1.85	1.20
0.10			0.43	0.97	0.48	0.13	1.70	0.14
0.24	1.93	1.46	0.24	1.83	1.41	0.09	0.78	0.60
0.15	1.72	1.28	0.22	2.04	1.48	0.06	0.79	0.58
0.61	4.08	2.98	0.62	5.31	3.91	0.26	1.96	1.47
0.15	2.03	1.51	0.11	1.88	1.42	0.15	1.20	0.88
	4.78	2.35						
0.35	2.06	1.20	0.23	1.68	0.98	0.07	0.87	0.61
0.15	2.17	1.47	0.33	2.96	2.25	0.14	1.10	0.79
0.52	4.26	3.09	0.63	4.35	3.31	0.22	2.19	1.58
0.52	3.10	2.39	0.38	2.48	1.97	0.19	1.20	0.93
0.25	1.95	1.30	0.18	1.48	1.12	0.12	0.83	0.53
0.51			0.10			0.10		
0.55	4.16	3.18	0.66	3.27	2.46	0.27	1.68	1.30
0.10	2.99	2.10	0.17	1.70	1.12	0.12	1.78	1.33
0.17	1.40	1.00	0.19	1.92	1.43	0.05	0.95	0.69
0.26	3.10	1.85	0.36	4.57	3.23	0.12	2.22	1.44
0.28	2.00	1.39	0.16	3.49	2.86	0.09	1.56	1.18
0.13	3.22	2.38	0.12	3.02	2.36	0.13	1.06	0.77
0.49			0.12			0.20		
0.28	2.06	1.41	0.14	1.30	0.96	0.08	0.86	0.61

Research Centre for the Management of Agricultural and Environmental Risks

ISBN 978-84-96655-79-9