Estimation of the virtual water trade between two Spanish regions: Castilla-la Mancha and Murcia

Ángel De Miguel, Eloy García and Irene De Buestamante

ABSTRACT

Virtual water is defined as the water needed to produce a product. We can use virtual water flow calculations to estimate the water efficiency of a country, as well as its economic dependence on water resources. Former studies on this area have focused on quantifying the virtual water flows between countries, in an international context. In this study we reduce the action framework to regions within a country, determining the virtual water balance between two Spanish regions: Castilla-La Mancha and Murcia. In 2004, Castilla-La Mancha exported to Murcia 2,453,442 tons of commercial products, from which 1,191,628 tons were agricultural goods. In terms of virtual water, it means 1,365 hm^3, including food-processing, and industrial products. It is necessary to add 350 hm^3 to the result, because of the water transfer (Tajo-Segura transfer) between the rivers basins of these regions, so the final virtual water number, in 2004, was 1,715 hm^3. The other way round, Murcia exported in 2004 2,069,000 tons of products, from which 490,351 tons were agricultural goods. That supposes 712 hm^3 of virtual water. Virtual water flow is unbalanced and displaced towards Murcia with a difference of 1,003 hm^3.

Key words | flow of goods, virtual water, virtual water trade, water consumption

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INTRODUCTION

Virtual water, a concept created by John Anthony Allan in the 1990s, refers to the water used in the production of a good, whether its origin is natural or manufactured (Allan 1998*a*,*b*). To estimate virtual water volume it is necessary to consider the complete production process, keeping in mind the impact of waste spills in water ecosystems.

One of the most important research papers in this field describes the methodology to estimate virtual water volume in different products (Chapagain & Hoekstra 2004), however most of the studies are concerned with the establishment of international water footprints (Chapagain & Hoekstra 2003*a*,*b*; Ma *et al.* 2006; Hoekstra & Chapagain 2007*a*,*b*; Hoekstra & Chapagain 2008). One step further will be to focus the analysis to specific areas, for instance, estimating virtual water flows within regions of a country.

Spain is one of the European countries with a higher degree, more than 30%, of water exploitation (annual consumption in comparison to the total resources), a fact which place Spain as the country with the third highest water deficit, after Malta and Cyprus. According to this situation it is vital to analyse deeply its water resources. Calculating the virtual water trade within regions is a helpful tool to improve national policies for efficient water resources management.

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ACTION FRAMEWORK

In this study, we have estimated virtual water flow to analyse the trade between two neighbouring regions within Spain, Castilla-La Mancha and Murcia.

The economies of both autonomous communities (regions) have a strong dependence on water, mainly due to the importance of agriculture in their economies. The use of water resources by agriculture is very intense, and in both of these communities studied it means 66% of the overall water consumed (OSE 2008).

Agriculture on the other hand employs about 10% of the economically active population (EAP), which is over the Spanish mean, estimate around 5%, of the EAP (INE 2005). Secondarily other productive sectors are important water consumers, such as the processing and transformation of agricultural, livestock and forest products, or the growing industrial and touristic activities (very dependent on water).

These two neighbouring regions have a water management conflict of interests, as they are connected through a water transfer between river basins, the so called Tajo-Segura water transfer.

The volume of the Tajo-Segura transfer varies between years (Morales *et al.* 2005) but is set to a maximum annual volume of 600 hm^3. The transfer channels water collected from the higher Tajo river basin in Castilla-La Mancha and discharges most of its resources as irrigation water in the Segura river basin, mainly in the region of Murcia.

OBJECTIVES

With this study, we intend to:

1. Estimate virtual water flow between the communities of Castilla-La Mancha and Murcia for 2004,
2. Calculate the water requirements of the different goods exchanged between both communities and
3. Compare the total flow of virtual water with the water resources existing in each region.

METHODS

To estimate virtual water flow between two regions we need to know two main variables: (1) the flow of goods between both regions and (2) the water consumed to produce trade goods (Figure 1). To estimate the water consumed, we have used the methodology proposed by Chapagain & Hoekstra (2004).

Estimates of virtual water for crops

Virtual water content of a certain crop *c* is the total water used for crop *c* in its growing period. VWC[*c*] is estimated using the following formula (Chapagain & Hoekstra 2004):

$$\mathrm{VWC}[c] = \frac{\mathrm{CWR}[c]}{Y[c]} \tag{1}$$

where, CWR is the water requirement of each particular crop species expressing of total evapotranspiration (including water from rain (green water) and water from irrigation (blue water)). Total evapotranspiration is estimate using the FAO Penman-Monteith equation (FAO 1998). *Y*[*c*] is the yield of a certain crop *c*.

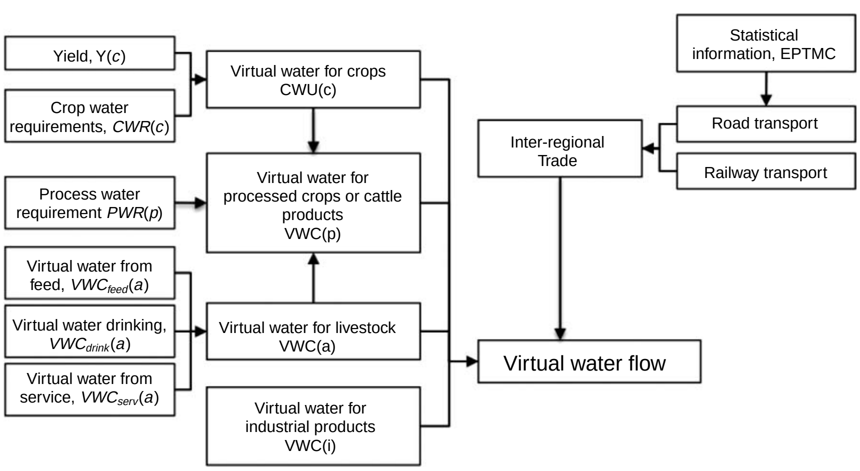

Figure 1 | Method to estimate inter-region virtual water flow.

Estimates of virtual water for livestock

Virtual water content of an animal a (VWC[a]) is defined by the following formula (Chapagain & Hoekstra 2003*b*):

$$\mathrm{VWC}[a] = \mathrm{VWC}_{\mathrm{feed}}[a] + \mathrm{VWC}_{\mathrm{drink}}[a] + \mathrm{VWC}_{\mathrm{serv}}[a] \quad (2)$$

where, $\mathrm{VWC}_{\mathrm{feed}}[a]$ accounts for the total volume of water used in the production of its feeding, $\mathrm{VWC}_{\mathrm{drink}}[a]$ accounts for the total drinking water used for its raising and $\mathrm{VWC}_{\mathrm{serv}}[a]$ accounts for the water used in cleaning and maintenance of the farming facilities.

Estimates of virtual water for processed crop or cattle products

Virtual water content of a processed product has to account for part of the water content of the primary crop or live animal from which it is derived and the water necessary for its transformation. The water necessary for it transformation is estimated using the following formula (Chapagain & Hoekstra 2003*b*):

$$\mathrm{PWR}[c, a] = \frac{Q_{\mathrm{proc}}[c, a]}{W[c, a]} \quad (3)$$

where, PWR[c,a] is the water needed to process one ton of primary crop c or cattle a into a processed product in a country measured as m^3/ton, $Q_{\mathrm{proc}}[c,a]$ is the water needed to process the crop c or animal a and $W[c,a]$ is the total weight of crop or animal processed.

The virtual water content of the primary crop or live animal is distributed over the different products from that specific crop or animal. To input the virtual water value of the primary crop or animal to its products, we have used the concept of *value* and *product* fraction (Chapagain & Hoekstra 2003*b*), where the product fraction $pf[p]$ of a product p is defined as the weight of the product obtained per ton of primary crop or live animal (raw material), and the value fraction $vf[p]$ of a product p is the ratio of the market value[1] $v[p]$ of the product to the aggregated market value of all the products obtained from the primary crop or live animal. If there are only one product obtained while processing a primary crop[2] or live animal, the value of $vf[p]$ will be one.

$$pf[p] = \frac{W_p[p]}{W[c, a]} \quad (4)$$

$$vf[p] = \frac{v[p]^* pf[p]}{\sum_{p=1}^{n_p} (v[p]^* pf[p])} \quad (5)$$

Thus the virtual water consumption VWC[p] of a product p is defined as the sum of the process water requirement PWR[c,a] and the virtual water consumption of the primary crop or animal, multiplied by the value and product fraction for each product (Chapagain & Hoekstra 2004).

$$\mathrm{VWC}[p] = (\mathrm{VWC}[c, a] + \mathrm{PWR}[c, a])^* \frac{vf[p]}{pf[p]} \quad (6)$$

Estimates of virtual water for the industry

The content of virtual water of an industrial product can be estimated in a similar manner to how it was calculated for agricultural products. However the high diversity of industrial products and production procedures complicates the calculation of virtual water. Chapagain & Hoekstra (2004), proposed to calculate virtual water by means of the GVA (Gross Value Added) of each sector, to which they give a certain volume of water.

We depart from data on the volume of trade goods in general, which makes it impossible to use the detailed method based on GVA. As for the whole country, industry only means 10% of virtual water (Chapagain & Hoekstra 2004); we have decided to give estimates of virtual water based on the estimates made for the food and agriculture sectors. We have used a value proportional to the resulting value for food and agriculture, applied to the importance of trade goods volume for the industrial sector of each community.

[1] In that case we assumed the market value is the same as the market price (conditions of market efficiency). It is defined as the economic price for which a good or service is offered in the marketplace (€/ton).

[2] When a primary crop or cattle is processed into a secondary product, there is often a loss of weight, because only part of the primary crop or cattle is used. In order to do this, we use the product fraction ($pf[p]$). When there is more than one product, we need to distribute the VWC of the primary crop or cattle into its output products, proportionally to the market price of the different products. To calculate it, we use the $vf[p]$. (Hoekstra & Chapagain 2008).

Estimates of the trade flows between regions

To estimate the virtual water flow between two regions, it is necessary to know beforehand the flow of goods between them. To minimise the error in estimating water flow, we need to know the types of products and in which amount are traded between these regions. There is no statistical information on the intra-national flow of goods in Spain (Llano 2004), so it is necessary to take into account the existing statistical information in transports, where road-transport is the main communication route (being 95%) between the two regions analysed (Alonso *et al.* 2003). There are not important flows by railway or by air. We have chosen as the most reliable source of information the EPTMC, permanent survey on road-transport of goods, done by the Ministry of Publics Works (Fomento 2005), included in the National Statistical Plan. In this survey we have not only information about the flow of goods, but the type of products traded among different regions. In this survey, goods are classified in 10 groups, divided again up to a total of 99 subgroups. It is important to verify the ETPMC data with the production statistics of each region to establish, precisely, the type of goods exchanged.

We have applied correction factors to reduce the estimation errors: (1) gross weight factor (gwf) to eliminate possible errors due to packaging and containers; (2) imported correction factor (if) to eliminate possible errors due the origin of goods. There is a volume of goods produced abroad, so it is important to estimate it, and eliminate it in the final flow. In the case of Murcia, this volume is bigger, due to the maritime transport. We have proposed the following methodology to estimate the corrected volume of a product p from a region r ($V_c[p,r]$):

$$V_C[p,r] = V_T[p,r]^* \mathrm{gwf}[p]^* \mathrm{if}[p,r] \tag{7}$$

where, $V_T[p,r]$ is the total volume of product p transfer from a region r to another specific region, gwf[p] is gross weight correction factor (is a percentage of the total volume transferred and depends on each good) and if[p,r] is the imported correction factor of a product p in a region r. if[p,r] is estimated with the following formula:

$$\mathrm{if}[p,r] = \frac{V_p[p,r]}{V_p[p,r]^* V_I[p,r]} \tag{8}$$

where, $V_p[p,r]$ is the total production volume of a product p in a specific region r, and V_I [p,r] is the imported volume of a product p in that region. To know the imported volume of trades and the regional production volume, we have used the Statistical Yearbooks of each region (CREM 2006; IES 2005).

We have only applied these correction factors on the food and agricultural sector, because in the industrial sector, values are extracted from the first one. We have to keep in mind the bias introduced when using a survey; however, EPTMC is the most reliable source of information.

Once the water needs for each products and the volume and type of traded goods were calculated, we can estimate the virtual water flow between the two regions. Figure 1 shows the main steps to estimate virtual water flows.

RESULTS

Virtual water flow from Castilla-la Mancha to Murcia

The volume of virtual water corresponding to traded goods is estimated as 1,365 hm^3 (Table 1). Within food and agriculture sector, food and forage means 40% of total virtual water. The products of this category are processed crop or cattle products, such as wine, cheese, eggs and milk. These processed products have high water requirements, and as they mean up to 23% of total traded goods, the sum up to 560 hm^3 of virtual water. Secondarily, cereals, with barley as the main crop, mean 23% of total virtual water (337 hm^3), oil products with 7.3% (100 hm^3), and wood and cork with 6.1% of total virtual water (83 hm^3).

For the industrial sector we assume a volume of 10% of total virtual water, being consistent with the mean value estimated for the whole country (Chapagain & Hoekstra 2004), as industrial products mean a 42% of the total amount of transported goods. Analysing the amounts of traded goods, we observe that the most important group of transported industrial products corresponds to low water use products as: mortar, limes and manufactured building materials on one hand, meaning 16% of total transported goods, and raw and manufactured mineral products meaning 15% of the total (MMA 2008).

Table 1 | Traded goods and virtual water flows from Castilla-La Mancha to Murcia

Virtual water flow (CLM–Mu)	Transported goods (tons)	Percentage of total traded goods	Percentage virtual water[3]	Virtual water volume (hm^3)
Food and agriculture products				
Cereals	382,358	16.5	24.5	337.2
Potatoes, fresh and frozen vegetables	206,021	9.4	2.9	39.28
Livestock and sugar beetroot	16,018	0.8	2.8	38.74
Wood and cork	56,408	2.0	6.1	82.63
Textiles and animal or vegetal materials	2,975	0.1	0.6	8.31
Food and forage	512,971	23.4	40.8	560.89
Oil	14,877	0.8	7.3	99.95
	1,191,628		1,167.01	
Industrial products	–	4.,0	10.0	129.7
Transported by train	–	5.0	5.0	68.24
Total virtual water				1,365 hm^3
Water from the transfer Tajo–Segura river basins				350 hm^3
Total water flow				1,715 hm^3

To have a more general view of water relations between both regions, it is necessary to add to virtual water obtained through trade values an extra volume of 350 hm^3 of virtual water accounting (fresh water) for the water exported through the Tajo-Segura transfer mentioned before (CREM 2006).

Virtual water flow from Murcia to Castilla-La Mancha

The volume of virtual water corresponding to traded goods is estimated as 712.1 hm^3 (Table 2).

Within food and agriculture sector, livestock and sugar beetroot mean 40% of total virtual water (274.16 hm^3), with pork as the main livestock product. This group of products is very water demanding even if cattle breeding scores third in volume of transported goods (4.7%), after the groups of food and forage (25.5%) and potatoes, fresh and frozen vegetables (6.4%). On the other hand, food and forage group of products mean 24% (173 hm^3) of virtual water, even if they have the highest volume of transported goods of all groups (25.5%). This is because most products in this group have low water requirements, such is the case of vegetables for human use, fruit juice and fish products.

We have to take into consideration the fact, that Murcia is a maritime region and has an important commercial port activity in Cartagena. Commercial port activities mean an important input of goods in the regional economy. For example, the volume of imported cereals is eight times higher than the volume produced in Murcia, or the volume of wood and cork products is almost entirely imported. These goods that have a foreign origin may not be accounted when estimating the flow of virtual water between these two regions, and we have used the previously mentioned correction factor (Equations (7) and (8)).

The industrial sector means 57% of total volume of exchanged goods, so we have set its volume of virtual water of 15%. The traded goods in this group are within the lowest water consumers, as is the case of petrol products (30% of the total volume of transported goods), cements, limes and manufactured building materials (13%) or manufactured mineral products (5% of the total volume of transported goods).

Virtual water trade between both regions

The virtual water trade between Castilla-La Mancha and Murcia is highly unbalanced. If we only take into account

[3] Equations (1), (2) and (6) are used to estimate the VW volume of the different products traded. This column represents the percentage of VW of a group on the total VW interchanged.

Table 2 | Traded goods and virtual water flow from Murcia to Castilla-La Mancha

Virtual water flow (Mu –CLM)	Transported goods (tons)	Percentage of total traded goods	Percentage virtual water	Virtual water volume (hm^3)
Food and agriculture products				
Cereals	10,953	0.9	1.8	12.67
Potatoes, fresh and frozen vegetables	81,048	6.4	4.3	31.29
Livestock and sugar beetroot	59,994	4.7	38.2	274.16
Wood and cork	890	0.1	0.4	2.76
Textiles and animal or vegetal materials	1,616	0.1	0.6	4.01
Food and forage	324,309	25.5	24.1	172.58
Oil	11,542	0.9	10.7	77.54
	490,352			575.1
Industrial products	–	56.5	15.0	101.8 hm^3
Transported by train	–	5	5.0	35.6 hm^3
Total water flow				712.1 hm^3

the volume of traded goods, the flow of virtual water from Castilla-La Mancha to Murcia (1,365 hm^3) almost doubles the flow on the opposite direction (712,1 hm^3), due to the types of goods exchanged and the difference of about 700,000 Tm between both directions. If we add up the volume of water transferred between Tajo and Segura river basins the trade becomes even more unbalanced towards Murcia (1,715 hm^3 opposite 712.1 hm^3) (Figure 2).

Virtual water flow versus available natural resources

Regarding the relation between flows and resources in each region in the food and agriculture sector, it is important to

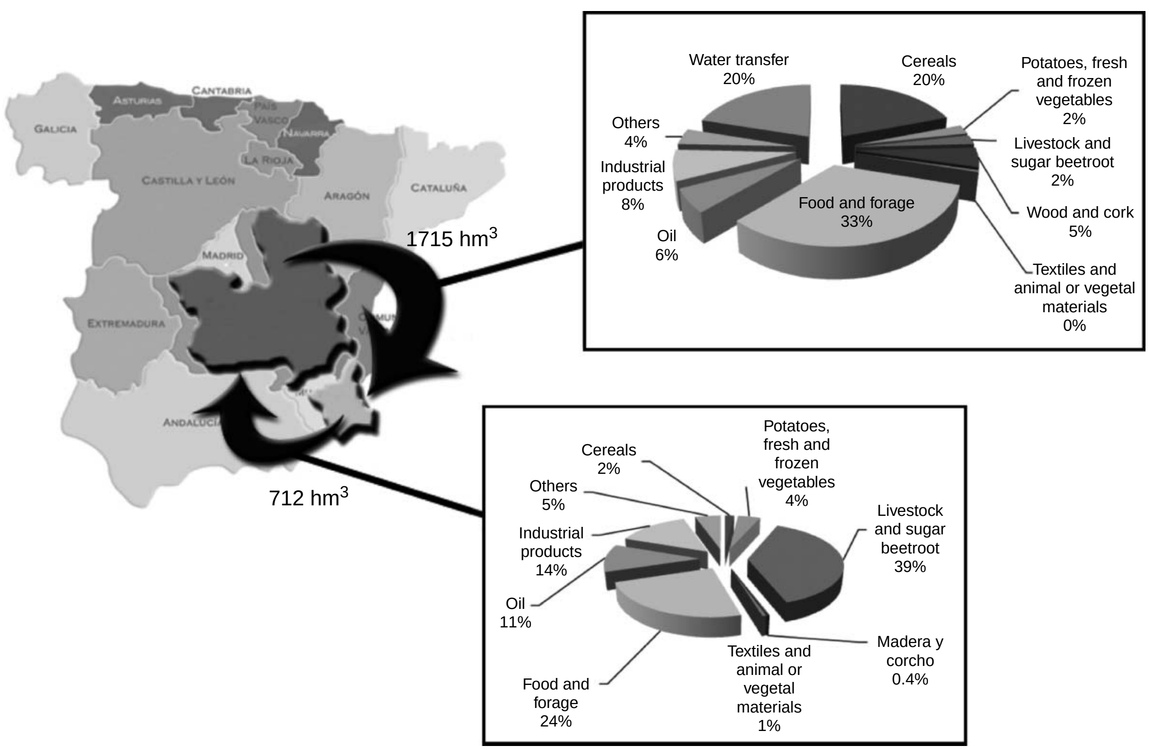

Figure 2 | Virtual water flow between Castilla-la Mancha and Murcia.

Table 3 | Traded goods and virtual water flow between Murcia and Castilla-la Mancha

Goods	Value ($/Tm)	Goods	Value ($/Tm)
Wheat	125–150	Vegetables	757
Barley	134	Sunflower	294
Corn	125	Oil	294
Tomatoes	856	Coffee	2,036
Pork	1,500	Lemon	1,600

indicate that most of the water resources comes from natural rainfalls (green water), while only a small part comes from irrigation (blue water) (Llamas 2005). Castilla-La Mancha, with a mean rainfall of 468.2 mm in 2004, had a total of 37,204 hm^3 of green water and a contribution of 17,634 hm^3 in blue water, so from the total water 1,167 hm^3 has been used to produce the traded goods with Murcia. Murcia, with a mean rainfall of 348.3 mm in 2004, has a total of 3,940 $hm^3$of green water and 620 hm^3 of blue water, so has used a total of 572 hm^3 to produced the traded goods.

The commercial exchanges between the two regions studied only mean a small part of the total volume exported. The amount of goods exported from Murcia to CLM means a low 10% of the total exports (20,244,000 Tm), whereas the amount of goods exported from CLM to Murcia only means 6.5% of the total volume of exports (37,744,000 Tm) (Fomento 2006).

If we assume that the trade of virtual water with other regions is similar to that studied, we could extrapolate the values of total commercial exchange for each region to estimate the total amount of virtual water exported. This extrapolation is merely approximate as the type of goods exported to other regions could be very different, and so its content of virtual water.

Assuming this approximation, we could conclude that the total volume of virtual water exported by Castilla-La Mancha is about 17,953 hm^3 which means about 50% of the annual volume of water available for the region. For Murcia the total amount of virtual water exports is of 5,720 hm^3, which is higher than the amount of precipitation water received for the whole surface of the region (3,940 hm^3).

CONCLUSIONS

Considering that virtual water flow existing between Castilla-La Mancha and Murcia is about 1,003 hm^3 higher than the flow between Murcia and Castilla-La Mancha, we can say that Murcia is a net virtual water importer, and Castilla-La Mancha is a net virtual water exporter.

Regarding Castilla-La Mancha each ton of food trade in agriculture sector means 979 m^3 while for Murcia it means 1,172 m^3/Tm. This means that Murcia needs almost 200 m^3 more to produce 1 ton of food and agricultural products. This is due to the type of goods transported, predominantly from the group of livestock and sugar beetroot. Above all Murcia is the 5th largest exporter in swine within Spain (Segrelles 1992), and the production of this has a high demand for water (4,400 L/kg).

We could state that most of the water resources of both regions are used in producing goods that are exported to other regions, more evidently in the case of Murcia where water availability is much lower.

Although this study is not focussed on setting a relationship between virtual water and the monetary value of exchanged goods[4], we can state that in Murcia the use of water is more productive, as better economic performance per unit of water is obtained.

The reasons for this are that: (i) in Murcia there is greater volume of industrial products with lower water demands and higher economical benefits and (ii) the relative importance of livestock and vegetable crops. On the other hand we could say that Castilla-La Mancha has a lower economical performance as cereal crops are an important part of the total of exchanged goods, and they are products with a high water demand and a low gross value added (Chapagain & Hoekstra 2004) (Table 3). It is necessary to point out that when talking about the performance of water, we are only referring to productive activities and not to other economic uses, such as tourist activities.

With this study, we have demonstrated that we can use the methodology proposal by Chapagain & Hoekstra (2004) to establish the most important flows of virtual water inside a country. With the statistical information, the main problems are to estimate the foreign goods. But we could

[4] This study is not focused on determining the economic efficiency of VW (€/m^3). Although, we have used the market price to distribute the VW of the primary crop or cattle into its secondary products (Equation (5)), it does not mean that a relationship have been established between the economic value of the goods and their water requirements.

do it with the relation of the imported trades and regional production, so we could solve it with the proposal methodology. Still it would be necessary to accomplish a full survey on virtual water trade for the country and not just two separate regions to give the manager a good tool to improve national policies for efficient water resources management.

REFERENCES

Allan, J. A. 1998*a* Watersheds and problemsheds: explaining the absence of armed conflict over water in Middle East. *Middle East Rev. Int. Aff.* **2**(1), 49–51.

Allan, J. A. 1998*b* Virtual water: a strategic resource, global Solutions to regional deficits. *Groundwater* **36**(4), 545–546.

Alonso, J., Pérez, J., Roca, A. & Pagés, L. 2003 La apertura exterior de las regiones en España: evolución del comercio interregional e internacional de las Comunidades Autónomas (The external opening of the Spanish regions: evolution of interregional and international trade of the Autonomous Communities). Tirant lo Blanch.

Chapagain, A. K. & Hoekstra, A. Y. 2003*a* The water needed to have the Dutch drink coffee. Value of Water Research Report Series No. 14, UNESCO–IHE, Delft, The Netherlands.

Chapagain, A. K. & Hoekstra, A. Y. 2003*b* Virtual water flows between nations in relation to trade in livestock and livestock products. Value of Water Research Report Series No. 12, UNESCO–IHE, Delft, The Netherlands.

Chapagain, A. K. & Hoekstra, A. Y. 2004 Water footprints of nations, Value of Water Research Report Series No. 16, UNESCO–IHE, Delft, The Netherlands.

CREM 2006 Anuario Estadístico de la Región de Murcia (Statistical Yearbook of Murcia). Centro Regional de Estadísticas de Murcia.

FAO 1998 Crop evapotranspiration–Guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56, Rome.

Fomento 2005 Encuesta permanente de Transporte de Mercancías por carretera (permanent survey on road-transport of goods). Ministerio de Fomento. Dirección general de programación económica y Subdirección general de estadística y estudios.

Fomento 2006 Anuario Estadístico (Statistical Yearbook). Ministerio de Fomento. Dirección general de programación económica y Subdirección general de estadística y estudios.

Hoekstra, A. Y. & Chapagain, A. K. 2007*a* The water footprints of Morocco and the Netherlands: global water use as a result of domestic consumption of agricultural commodities. *Ecol. Econ.* **64**(1), 143–151.

Hoekstra, A. Y. & Chapagain, A. K. 2007*b* Water footprints of nations: water use by people as a function of their consumption pattern. *Water Res. Manag.* **21**(1), 35–48.

Hoekstra, A. Y. & Chapagain, A. K. 2008 *Globalization of Water: Sharing the Planet's Freshwater Resources*. Blackwell Publishing, Oxford.

IES 2005 Anuario Estadístico (Statistical Yearbook). Instituto Estadístico de Castilla-La Mancha.

INE 2005 Encuesta de Población Activa (Labor Force Survey). Instituto Nacional de Estadística.

Llamas, M. 2005 Los colores del agua, el agua virtual y los conflictos hídricos (Colors of water, virtual water and water conflicts). *Revista de la Real Academia de Ciencias Exactas, Físicas y Naturales* **99**(2), 369–389.

Llano, C. 2004 Economía sectorial y espacial: el comercio interregional en el marco input-output (Sectoral and spatial economy: trade interregional input-output Framework). PhD thesis. Instituto de Estudios Fiscales. Ministerio de Economía y Hacienda. Colección Investigaciones: N°1/2004.

Ma, J., Hoekstra, A. Y., Wang, H., Chapagain, A. K., & Wang, D. 2006 Virtual versus real water transfers within China. *Phil. Trans. R Soc.* **361**, 835–842.

MMA 2008 El agua en la economía española, situación y perspectivas. Informe integrado del análisis económico de los usos (Water in the Spanish economy, status and perspectives. Integrated report uses economic analysis). Ministerio de Medio Ambiente. Grupo de análisis económico.

Morales Gil, A., Rico, A. M. & Hernández, H. M. 2005 El trasvase Tajo-Segura (The Tajo-Segura water transfer). *Observatorio medioambiental* **8**, 73–110.

OSE 2008 Agua y sostenibilidad: funcionalidad de las cuencas (Water and sustainability: river basin funcionality). Observatorio de la Sostenibilidad. Ministerio de Medio Ambiente, Medio Rural y Marino.

Segrelles, S. J. 1992 El comercio interprovincial de Ganado porcino en España (Interegional trade of swine in Spain). *Investigaciones geográficas* **10**, 197–213.

Water Footprint Network 2009 http://www.waterfootprint.org/?page=files/home (accessed 20 November 2009).

APPENDIX I. SYMBOLS

Symbol	Unit	Description
CWR [c]	m^3/ha	Crop water requirement of crop c
gwf[*p*]	–	Gross weigth factor
If[*p*,*r*]	–	Imported factor for a product *p* in a region *r*
pf[*p*]	–	Product fraction of a product *p*
PWR [*c*,*a*]	m^3/t	Process water requirement per ton of crop *c*, or animal *a*
$Q_{\mathrm{proc}}[c,a]$	m^3	Water needed to process a crop *c*, or an animal *a*
vf[*p*]	–	Value fraction of a product *p*
v[*p*]	€/t	Average market price of product *p*
$V_c[p,r]$	t	Corrected volume of product *p* from a region *r*
$V_I[p,r]$	t	Imported volume of a product *p* in a region *r*
$V_T[p,r]$	t	Total volume of product *p* transfer from a region *r* to another specific region
$V_p[p,r]$	t	Total production of a product *p* in a region *r*
VW	m^3/t	Virtual Water
VWC[*a*]	m^3/t	Virtual water content of live animal *a*
VWC[*c*]	m^3/t	Virtual water content of crop *c*
VWC[*i*]	m^3/t	Virtual water content of industrial product *i*
VWC[*p*]	m^3/t	Virtual water content of processed product *p* (secondary and thirdly products)
$\mathrm{VWC}_{feed}[a]$	m^3/t	Virtual water content of live animal *a* related to feeding
$\mathrm{VWC}_{drink}[a]$	m^3/t	Virtual water content of live animal *a* related to drinking
$\mathrm{VWC}_{serv}[a]$	m^3/t	Virtual water content of live animal *a* related use of "service water"
W[*c*,*a*]	t	Weight of crop *c* or animal *a* processed
$W_p[p]$	t	Weight or primary product *p*
Y[*c*]	ton/ha	Yield of crop *c*

APPENDIX II. GLOSSARY OF TERMS

Terms	Definition
"Blue" water	The "blue" virtual-water content of a product is the volume of surface water or groundwater that evaporated as a result of the production of the product. In the case of crop production, the blue water content of a crop is defined as the sum of the evaporation of irrigation water from the field and the evaporation of water from irrigation canals and artificial storage reservoirs.
Fresh water	Term used to differentiate between real and virtual water. In this case, refers to water from an inter-basin transfers
Intra-national flow	The flow of goods (crops, animal or industrial product) traded between different regions within the same country.
"Green" water	The "green" virtual-water content of a product is the volume of rainwater that evaporated during the production process. It is stored in the unsaturated zone of soil.
Primary crops or live animal	It is the initial unit from which the virtual water calculations are made. In the case of a product of agricultural origin, is the crop. In the case of products of animal origin, will be the living animal.
Virtual Water	The virtual water content of a product (a commodity, good or service) is the volume of freshwater used to produce the product, measured at the place where the product was actually produced (production-site definition)
Water exploitation	Index shows available water resources in a country or region compared to the amount of water used.
Water footprint	The water footprint is an indicator of water use that looks at both direct and indirect water use of a consumer or producer. The water footprint of an individual, community or business is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community or produced by the business.

Note: Data source from Water Footprint Network (2009).