WP 3.4 Guadiana Case Study

Water Footprint analysis (hydrologic and economic) of the Guadiana river basin within the NeWater project

Report of the NeWater project -
New Approaches to Adaptive Water Management under Uncertainty
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Summary

In most arid and semiarid countries, water resource management is an issue as important as controversial. Today most water resources experts admit that water conflicts are not caused by the physical water scarcity but they are mainly due to poor water management or governance. The virtual water concept, defined as the volume of water used in the production of a commodity, good or service, together with the water footprint (water volume used to produce the goods and services consumed by a person or community), links a large range of sectors and issues, providing an appropriate framework to find potential solutions and contribute to a better management of water resources, particularly in arid or semi-arid countries.

As the most arid country in the European Union, water use and management in Spain is a hot political and social topic. The transboundary Guadiana river basin located in south-central Spain and Portugal drains an area of 66,800km^2, of which 17% lies in Portugal. The present analysis is carried out in the Spanish side of the basin which has been divided in Upper, Middle, Lower Guadiana basin and TOP domain. The TOP domain is a group of three small river basins located near the Guadiana River mouth. In these regions the main green and blue water consuming sector is irrigation, with about 95% of total water consumption. Within this sector, high virtual-water low-economic value crops are widespread in the studied Upper and Middle Guadiana regions, prevailing cereals with low blue water economic productivity. In particular, the Upper Guadiana basin is among the most significant in Spain in terms of conflicts between agriculture, with almost no food (virtual water) import, and the conservation of rivers and groundwater-dependent wetlands. On the other hand, in the Lower Guadiana basin and TOP domain growing vegetables and crops under plastic green houses, the blue water economic productivity values are much higher, using jointly surface and groundwater resources. The amount of crops and the employment generated in the whole Guadiana basin is already producing "more crops and jobs per drop". The aim now is to move towards the policy “more cash and nature per drop”, at least on the Upper and Middle Guadiana basin.

The implementation of the Water Framework Directive (WFD) requires achieving good status of groundwater and surface water in Europe by 2015. In order to achieve WFD

objectives, and framed within the European NeWater project, the present study analyses the virtual water, water footprint and economic value of the different economic sectors, crop virtual water content and value, and related political issues. Within this context, the virtual water and water footprint hydrologic and economic analysis provide a multidisciplinary framework for informing and optimising production and trade decisions, contributing thus to a better management and allocation of water resources. A significant innovation of this work is not only to consider the economic and hydrological aspects of the water footprint, but also to differentiate between the green and blue water components at a river basin level. Another significant innovation is that the irrigation with surface and groundwater are separately analyzed. In summary, the methodology applied in this analysis, considering together hydrological and economic data and separating the use of green and blue surface and groundwater seems to be innovative and useful.

1. Introduction

In most arid and semiarid countries, water resource management is an issue as important as controversial. Today most water resources experts admit that water conflicts are not caused by the physical water scarcity but they are mainly due to poor water management. The virtual water and water footprint analysis, linking a large range of sectors and issues, provides an appropriate framework to find potential solutions and contribute to a better management of water resources, particularly in water scarce countries.

The water footprint (WF) is a consumption-based indicator of water use defined as the total volume of water that is used to produce the goods and services consumed by an individual or community (Hoekstra and Chapagain, 2008). Closely linked to the concept of water footprint is the virtual water. The virtual water content of a product (a commodity, good or service) refers to the volume of water used in its production (Allan, 1997; 1999). Building on this concept, virtual water 'trade' represents the amount of water embedded in traded products (Hoekstra and Hung, 2002). A nation can preserve its domestic water resources by importing water intensive products instead of producing them domestically (ibid.). These 'water savings' can be used to produce alternative, higher-value agricultural crops, to support environmental services, or to serve growing domestic needs. Thus, virtual water 'import' is increasingly perceived as an alternative source of water for some water-stressed nations and is starting to change the current concepts of water and food security.

Furthermore, the virtual water and water footprint analysis makes explicit how much water is needed to produce different goods and services. In semi-arid and arid areas, knowing the virtual water value of a good or service can be useful towards determining how best to use the scarce water available. In this sense, it is important to establish whether the water used proceeds from rainwater evaporated during the production process (green water) or surface water and/or groundwater evaporated as a result of the production of the product (blue water) (Chapagain *et al*., 2006; Falkenmark, 2003). Traditionally, emphasis has been given to the concept of blue water through the "miracle" of irrigation systems. However, an increasing number of authors highlight the importance of green water (Allan, 2006; Comprehensive Assessment of Water Management in

Agriculture, 2007; Falkenmark and Rockström, 2004; Rockström, 2001; Zygmunt, 2007). Virtual water and water footprint assessment could thus inform production and trade decisions, promoting the production of goods most suited to local environmental conditions and the development and adoption of water efficient technology. Adopting this approach, however, requires a good understanding of the impacts of such policies on socio-cultural, economic and environmental conditions. Besides, water is not the only factor of production and other factors, such as energy, may come to play an increasingly important role in determining water resources allocation and use.

The present scheme deals with the economic and hydrological analysis of the virtual water and water footprint of the Guadiana river basin, considering both green and blue (surface and groundwater) water of the different economic sectors. This could facilitate a more efficient allocation and use of water resources, providing simultaneously a transparent interdisciplinary framework for policy formulation. Even if the Guadiana river basin is shared by Spain and Portugal, this report focuses on the Spanish area of the river basin. The analysis of the Portuguese area (less than 20% of the total area of the basin) will be carried out by the Portuguese INAG (National Water Authority). It analyses the water footprint, virtual water and economic relevance of each economic sector at different spatial scales in different rainfall years (evaluating an average - 2001, dry -2005, and humid year -1997). Special emphasis is given to the agricultural sector, which consumes about 95% of total green and blue water resources. First of all two specific agricultural regions are analysed: Mancha in the Upper Guadiana basin and Don Benito in the Middle Guadiana. Second, the whole Guadiana is evaluated, which has been divided in four sections: groundwater based Upper Guadiana basin, mainly surface water based Middle basin, both groundwater and surface water based Lower Guadiana basin and the former Lower Guadiana or Guadiana II (henceforth TOP domain)[1] comprising the Tinto, Odiel and Piedras river basins. At the end of each chapter virtual water 'trade' is evaluated. Finally, crop water consumption estimates are assessed against the results obtained by other national and international studies. A glossary with key terms is also included at the end of the study. It concludes that a better knowledge of the water

1 Even if before the 1 January 2006 the TOP domain was the competence of the Guadiana River Basin Authority, after this date it was transferred to the Government of Andalusia.

footprint and virtual water 'trade' in the semiarid Guadiana basin provides a transparent and multidisciplinary framework for informing and optimising water policy decisions, contributing at the same time to the implementation of the EU Water Framework Directive (2000/60/EC). As a whole the Guadiana river basin has already achieved a good degree of the paradigm "more crops and jobs per drop" but it is still far from achieving "more cash and nature per drop". An exception for this is the case of the Lower Guadiana basin and TOP domain in Andalusia, where water-extensive high economic value crops adapted to the Mediterranean climate are grown, essentially vegetables, fruits and olive oil. For the time being and almost in the entire world, water footprint analysis has focused on hydrological aspects. A significant innovation of this work is to emphasize the imperative challenge of considering economic and ecological aspects, with the aim of going towards the new paradigm "more cash and nature per drop" (Aldaya *et al*., 2008). Finally, the water footprint analysis is providing new data and perspectives that are enabling to get a more optimistic outlook of the frequently spread looming «water scarcity crisis». We expect that this new knowledge makes traditional water and food security concepts change, concepts that have hitherto prevailed in the minds of most policy makers.

2. Scope and aims

This scheme aims to analyse the virtual water and water footprint, both from a hydrological and economic perspective, in the Guadiana semiarid basin within the NeWater project in order to achieve a more efficient allocation of water resources adapted to the current and future situation. For this purpose, the crop water requirements and productivities have been assessed in different rainfall years (evaluating an average, dry and humid year) at different spatial scales (agricultural region level and river basin scale).

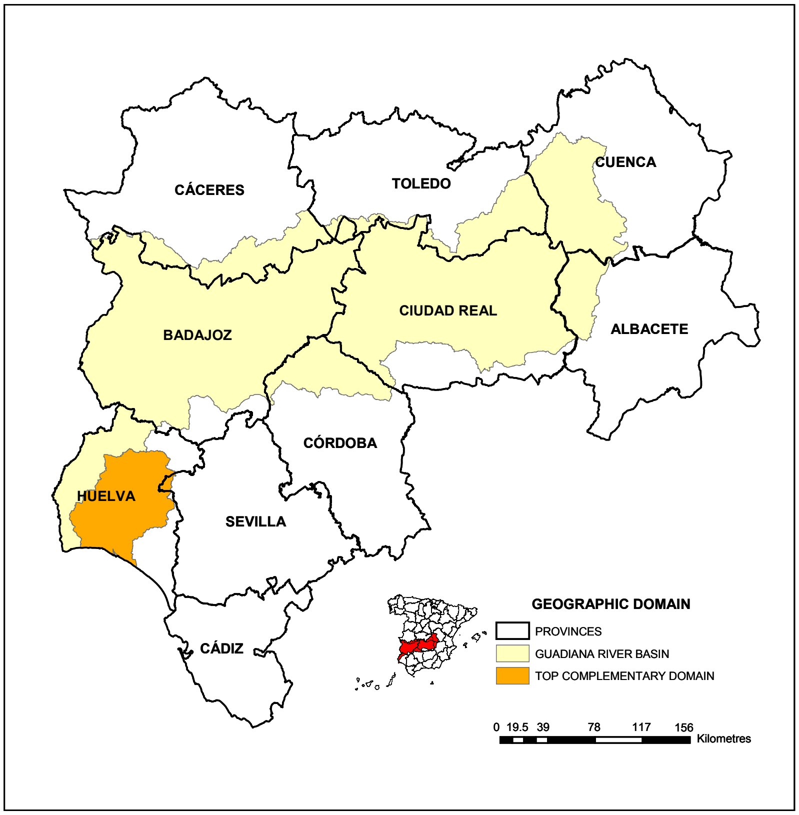
Since the Guadiana river basin is shared by Spain and Portugal, this report will focus on the Spanish side of the river while the Portuguese side of the basin will be analysed by the Portuguese Water Authority (INAG) according to the letter signed on 27 September 2007 by Orlando Borges, President of INAG. Dealing with this issue will facilitate the transboundary cooperation between the riparian states considered within the NeWater project. Framed within the NeWater project, this research is closely related to the broader project "Water Footprint of Spain" sponsored by the Marcelino Botín Foundation under the direction of Prof. M.R. Llamas and carried out by the Agricultural Economics Department from the Polytechnic University of Madrid (UPM), chaired by Prof. Garrido and Varela (Aldaya *et al.*, 2008 and in preparation). A written memorandum of understanding on this collaboration was signed by the Director General of the Botin Foundation and the leader of the Guadiana NeWater case study.

3. Study area

River basin scale

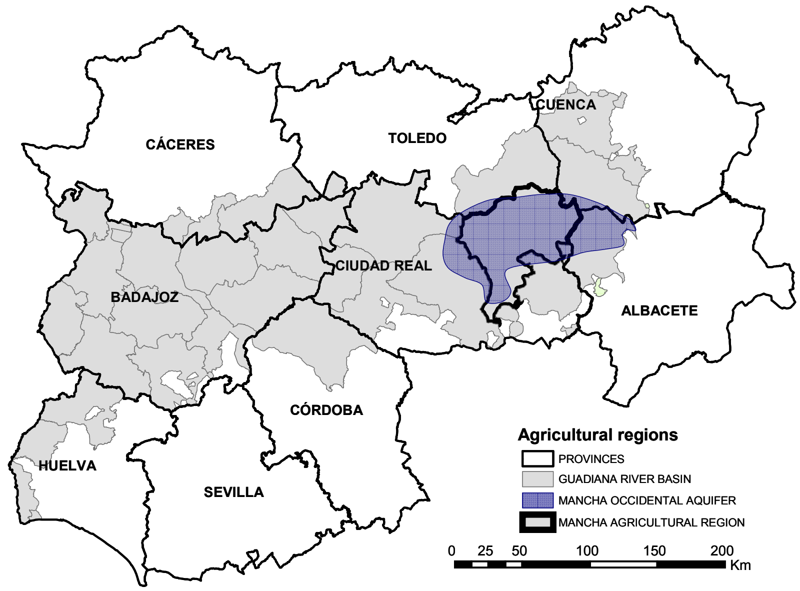
For practical purposes, the basin has been divided in four areas (Figure 1): a) groundwater based Upper Guadiana basin (totally located in a part of the Castilla-La Mancha Autonomous region); b) mainly surface water based Middle Guadiana basin (comprising part of Extremadura but not the small fraction of Cordoba); c) the Lower Guadiana basin (including the part of the basin in Huelva); and d) TOP domain (comprising the Tinto, Odiel and Piedras river basins). The TOP domain was the competence of the Guadiana River Basin Authority before 1 January 2006, but its competence was then transferred to the Government of Andalusia (CHG, 2008a).

Figure 1. Guadiana river basin geographic and administrative domain from 1 January 2006 onwards (CHG, 2008a)



According to CHG (2008b) when referring to the Guadiana river basin on the whole ('Total Guadiana' in the present document), it includes the Upper, Middle and Lower basins including the small fraction of Cordoba.

Figure 2. Western Mancha aquifer location within the Upper Guadiana Basin. Modified from CHG (2008b).



The Upper Guadiana basin, located in Castilla-La Mancha, and including the Mancha agricultural region, is one of the driest river basins in Spain (Hernández-Mora *et al*., 2003). In this part, UNESCO recognized the collective ecological importance of 25,000 ha of wetlands in 1980, when it designated the "Mancha Húmeda" Biosphere Reserve. In a largely arid region, these wetlands provided crucial nesting and feeding grounds for European migrating bird populations and were home to rare animal and plant species. The Tablas de Daimiel National Park (2,000 ha), a Ramsar Site, stands out for its significance as a symbol for the Spanish conservation movement. Today, however, this wetland that used to receive the natural discharge from the Western Mancha aquifer (Figure 2), survive artificially, in a kind of "ecological coma", thanks to the water transfers that come from the Tagus-Segura Aqueduct starting in 1988 (Hernández-Mora *et al*., 2003) and to the artificial pumpage of groundwater to maintain flooded about the 5% of the 2,000 hectares of wetlands in the undisturbed National Park. More recently, some NGOs are claiming that "La Mancha Humeda, Biophere Reserve" should not be considered any more by UNESCO as a World Biosphere Reserve. On the other hand, in order to recover these ecosystems, the Spanish Government, at the proposal of the Ministry of the Environment, approved a Special Plan for the Upper Guadiana (*Plan Especial del Alto Guadiana* –PEAG) on 11 January 2008 (CHG, 2008c). The formal approval of this Plan includes a budget of 5,500 million euros to be spent during the next 20 years.

Detailed analysis at agricultural regional level

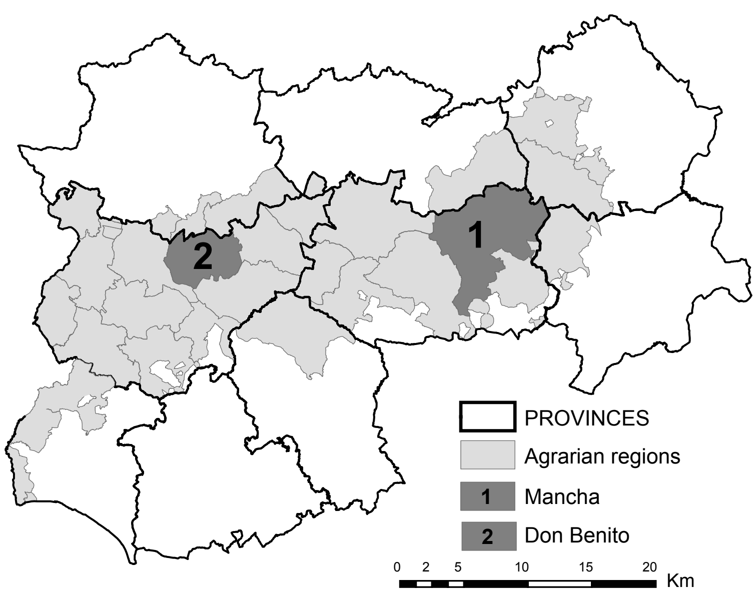
It is very interesting to analyse the virtual water and water footprint at different scales. In this work we have started from the small scale and then deal with the whole basin. Thus, we have firstly analysed two agricultural regions.

These two agricultural regions are located in different sections of the Guadiana Basin and have different characteristics (Figure 3):

1) Mancha agricultural region in the Upper Guadiana basin (Ciudad Real, in the Autonomous region of Castilla-La Mancha) – is the region with the highest groundwater irrigation proportion in the whole Guadiana basin (96%) (CHG, 2008b). This development has been done mainly by private farmers.

2) Don Benito agricultural region in the Middle Guadiana basin (Badajoz, in the Autonomous region of Extremadura) - is the region with the highest surface water irrigation proportion in the whole Guadiana basin (94%) (CHG, 2008b). This development has been done mainly by the Government with public funds.

Figure 3. Mancha (1) and Don Benito (2) agricultural regions within the Guadiana river basin. Modified from CHG (2008b).



The seven most representative crops in each area have been studied corresponding to about 70% of the total crop area for Mancha (Appendix 1.2) and 50% for Don Benito agrarian region (Appendix 1.3). When choosing the crops, not only the number of hectares has to be taken into account but also their economic productivity and water consumption.

4. Methodology

The present study estimates the virtual water and water footprint of the Guadiana river basin considering the green and blue water components for the most representative crops and the blue water component for livestock, industrial products and domestic (urban) water use. Within the blue water component, the volumes of surface and groundwater consumption are differentiated. In parallel with these analyses, economic data are studied. This is done at different spatial and time scales. First of all, two different agricultural regions are studied (Mancha and Don Benito) and then the whole river basin (Upper, Middle, Lower Guadiana and TOP domain). In every case this is done for an average (2001), dry (2005) and humid year (1997).

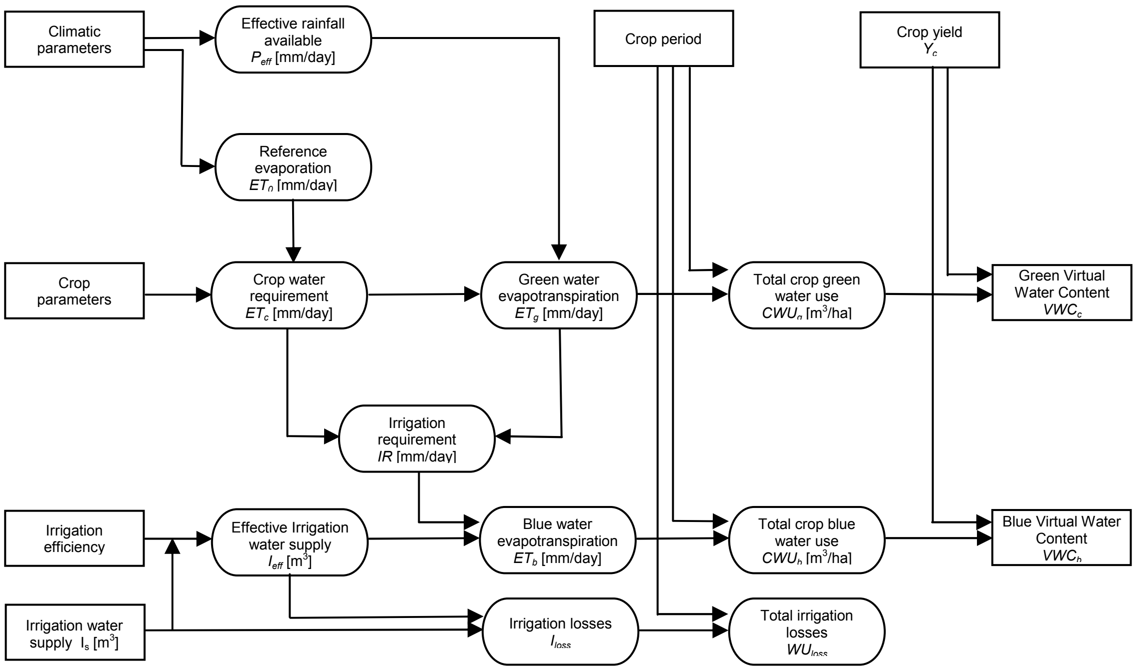
The virtual water and water footprint are calculated using the methodology developed by the Institute of Hydraulic Engineering (IHE) in the Netherlands: Hoekstra and Hung (2002; 2005) and Chapagain and Hoekstra (2003; 2004). For its emphasis on green and blue water, the present research follows recent works of Chapagain and Orr (2008), Chapagain *et al.* (2006) and Hoekstra and Chapagain (2008).

Virtual water content (V)

The virtual water content of a product (*V*) is the volume of freshwater used to produce the product, which depends on the water use in the various steps of the production chain. The virtual water content of a product breaks into a green and blue component. These components refer to evapotranspired rainwater and ground/surface water respectively.

The virtual water content of primary crops, i.e. crops in the form as they come directly from the land without having undergone any processing, was estimated in a number of steps following Hoekstra and Chapagain (2008).

Figure 4. Diagram to calculate the virtual water content of a primary crop. Modified from Chapagain and Orr (2008).



First, crop water requirements (*CWR*, mm/day) were calculated over the period from planting to harvest. The crop water requirement is the water needed for evapotranspiration under ideal growth conditions. "Ideal conditions" means that adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield (*Y*). The crop water requirement of a certain crop under particular climatic circumstances was estimated with the CROPWAT model developed by the Food and Agriculture Organization (Allen *et al*., 1998; FAO, 2003). Calculations were made with a time step of 5 days. This means that the average monthly rainfall input is distributed by the program every 5 days. In this model, basically, the crop water requirement is calculated by multiplying the reference crop evapotranspiration (ET_0, mm/day) by the crop coefficient (K_c):

$$CWR = Kc \times ET_0$$

The reference crop evapotranspiration (ET_o) is the evapotranspiration rate from a reference surface, not short of water. The reference is a hypothetical surface with extensive green grass cover with specific characteristics. The only factors affecting ET_0

are climatic parameters. ET_0 expresses the evaporating power of the atmosphere at a specific location and time of the year and does not consider the crop characteristics and soil factors. The actual crop evapotranspiration (ET_c) under ideal conditions differs distinctly from the ET_0, as the ground cover, canopy properties and aerodynamic resistance of the crop are different from grass. The effects of characteristics that distinguish field crops from grass are integrated into the crop coefficient (K_c).

With regard to the crop parameters, the crop coefficients in different crop development stages (initial, middle and late stage), the length of each crop in each development stage and the cropping calendar (planting and harvest dates) are used as input data to CROPWAT. For perennial crops, the planting dates can be assumed to be the green-up date, that is, the time when the initiation of new leaves occur, for the calculation of crop water requirements.

Apart from *CWR*, the CROPWAT model (Allen *et al*., 1998; FAO, 2003) was also used to estimate the effective rainfall (P_{eff}). From the few inbuilt options to estimate effective rainfall in this model, we have chosen the USDA SCS (USDA Soil Conservation Service), as it is one of the most widely used methods in estimating P_{eff} in agricultural water management (Chapagain and Orr, 2008). Effective rainfall is the part of the total amount of rainwater useful for meeting the water need of the crop, generally slightly less than the total rainfall because not all rainfall can actually be appropriated by the crop, e.g. due to surface runoff or quick percolation.

Next to effective rainfall, irrigation requirements have to be calculated over the full growing period. The irrigation requirement (*IR*, mm/day) is zero if effective rainfall is equal or larger than the crop water requirement at a certain time step (5 days), but else it is equal to the difference between crop water requirement (*CWR*, mm/day) and effective rainfall (P_{eff}, mm/day):

$$IR = \max\left(0, CWR - P_{eff}\right)$$

Green water evapotranspiration (ET_g, mm/day), i.e. evapotranspiration of rainfall, will be equal to the minimum of crop water requirement (*CWR*, mm/day) and effective rainfall (P_{eff}, mm/day). Similarly, blue water evapotraspiration (ET_b, mm/day), i.e. field-evapotranspiration of irrigated water, will be the minimum of irrigation requirement (*IR*, mm/day) and effective irrigation (I_{eff}, mm/day), which refers to the amount of irrigation water that is available for plant uptake:

$$ET_g = \min(CWR, P_{eff})$$

$$ET_b = \min(IR, I_{eff})$$

In practice, at the scale at which we work, we generally know little about available effective irrigation water. At best we can obtain data on ratios of irrigated to non-irrigated cropland areas. We are therefore forced to simply assume that throughout the growing period the amount of effective irrigation is zero in the case of non-irrigated or rainfed lands. This implies that ET_b is supposed to equal *IR* for the irrigated areas and assumed to be zero for the non-irrigated lands. In reality there are lands that are irrigated but not sufficiently to meet irrigation requirements at times, but this can only be dealt with if more detailed irrigation data are available. In our two cases we have preliminarily assumed that effective irrigation is equal to *IR* since in the Upper Guadiana basin groundwater irrigation the farmers pump practically always the necessary water and in the Middle Guadiana the buffering capacity of the existing huge reservoirs almost always guarantee the necessary irrigation. These assumptions will be checked with the farmers and the basin's Water Authority. In relation to groundwater irrigation in the Upper Guadiana basin it may not be realistic because, theoretically or legally, the amount of water that the farmers are allowed to pump may be significantly smaller than the IR. It is difficult to ascertain the degree of enforcement of the Guadiana Basin pumpage restrictions.

Total evapotraspiration from the crop field is the sum of the two above calculated components (ET_g and ET_b). All above-mentioned water flows are expressed in mm/day, but in CROPWAT calculations we actually apply a time step of 5 days, to account for the possibility of soil moisture storage. Temporary storage of rain or irrigation water in the soil makes it possible that surplus water in one day can be used by the plants in the next four days, so that a day-by-day comparison of crop water requirement and effective rainfall or irrigation water would decrease the ET_g and increase the ET_b.

The green and blue components in crop water use (*CWU*, m^3/ha) are calculated by accumulation of daily evapotranspiration over the complete growing period:

$$CWU_g = 10 \times \sum_{d=1}^{\lg p} ET_g$$

$$CWU_b = 10 \times \sum_{d=1}^{\lg p} ET_b$$

The factor *10* is meant to convert mm into m^3/ha. The summation is done over the period from the day of planting (day 1) to the day of harvest (*lgp* stands for length of growing period in days). Since different crop varieties can have substantial differences in the length of the growing period, this factor can significantly influence the calculated crop consumptive water use (*CWU*). The "green" crop consumptive water use (CWU_g) represents the total rainwater evapotranspiration from the field during the growing period; the "blue" crop consumptive water use (CWU_b) represents the total irrigation water evapopotranspiration from the field. Total crop consumptive water use – the sum of the above two components – is equal to the crop water requirements summed over the growing period if rainwater is sufficient throughout the growing period or if shortages are supplemented through irrigation.

The green component in the virtual water content of a primary crop (V_g, m^3/ton) is calculated as the CWU_g (m^3/ha) divided by the crop yield (*Y,* ton/ha). The blue component (V_b, m^3/ton) is calculated in a similar way, but should also include a component that refers to evaporation losses within the irrigation water storage and transport system. At this stage, we have not included this component as these data are not easily available. Since *Y* is different for rainfed and irrigated lands each of them has been estimated separately: calculating one green component (V_g) for rainfed areas and other V_g and V_b for irrigated lands:

$$V_g = \frac{CWU_g}{Y}$$

$$V_b = \frac{CWU_b}{Y}$$

It is highlighted that, in this preliminary study, the *IR* are always assumed to be met due to the huge reservoirs in the Middle Guadiana and aquifer in the Upper.

The total virtual water content of a primary crop (V, m^3/ton) is the sum of the green and blue components:

$$V = V_g + V_b$$

The green and blue components of virtual water content of crops were calculated separately for each agricultural region.

Crop water supply was estimated by dividing the crop consumptive water use (*CWU*) by the average global irrigation efficiency for each crop in the region.

Concerning vineyard, olive tree and tomato water consumption, when irrigated by localized irrigation, dual coefficients were applied following SIAR (2008).

Irrigation losses (I_{loss}) and the dilution volume of water, that is, the theoretical amount of water that would be required to dilute pollutants emitted during the production process, are not estimated in the present study.

Water footprint

In line with Chapagain and Hoekstra (2004), the water footprint of a country is equal to the total volume of water used, directly or indirectly, to produce the goods and services consumed by the inhabitants of the country. A national water footprint has two components, the internal and the external water footprint. The internal water footprint is defined as the volume of water used from domestic water resources to produce the goods and services consumed by the inhabitants of the region (Hoekstra and Hung, 2005). It is the sum of the total water volume used from the domestic water resources in the national economy minus the volume of virtual water export to other countries insofar related to export of domestically produced products (Chapagain and Hoekstra, 2004). The present study, however, will not subtract exports as data are not easily available. Along these lines, the external water footprint, which is the volume of water used in other regions to produce goods and services imported and consumed by the inhabitants of that region (ibid.), has not been calculated as trade data at a basin level are not easily available. Trade data at a provincial level are presented separately.

5. Data sources and limitations

In order to carry out this report, a number of simplifications have been assumed. First of all, the virtual water content values obtained with the CROPWAT model should be considered as a first approximation to reality. The main gaps in this approach are: a) the lack of data on the soils characteristics and their storage capacity for the effective rain; b) the amount of irrigation water "lost" from the surface reservoirs to the field; c) the amount of water necessary to abate the pollution; and d) the reduction in crop yield when the irrigation demand cannot be supplied. Second, the eight most representative crops in each area have been studied corresponding to about 80% of the total area (Appendix 1). In the case of the agricultural regions, the crops analysed represent 70% of the total crop area in Mancha and 50% in Don Benito. These are extrapolated to 100% of the total cultivated area; obviously these simplifications mean that the final data obtained should only be considered as preliminary approximations. Third, with the aim of analysing the impact of climate variability on the use of water resources three different rainfall years were chosen: a humid (1997), average (2001) and dry year (2005). The average rainfall in 2001 was about 355 mm in Castilla-La Mancha, 547 in Extremadura and and 510 mm in Andalucía. When available, data for these years were used. This was not possible, however, in every case as shown below in this chapter. Fourth, and following CHG (2008b) data, when estimating the urban water use, urban water supply and sanitation data have been taken into account. Fifth, concerning the industrial water use, since energy and building industry are not considered within the industrial sector, hydroelectric energy was not included (CHG, 2008b). Sixth, with regard to the livestock water consumption, the drinking water and water to clean its housing is considered, leaving out the water used to grow and process its fodder. This is important when comparing these data with other analyses of the livestock water footprint. Finally, data have been compiled from different sources.

- Geographic and social data

Data related to human population and employment by agricultural region were taken from the Guadiana River Basin Authority (CHG, 2008b).

- Climatic data

Average monthly rainfall and evapotranspiration data at provincial level, as an input for the CROPWAT model (FAO, 2003), were obtained from the National Institute of Meteorology (INM, 2007).

- Agricultural data

Data related to area (total area, crop area both rainfed and irrigated, irrigated area by irrigation system) by agricultural region were taken from the Guadiana River Basin Authority (CHG, 2008b) and the Spanish Ministry of Agriculture, Fisheries and Food 1T sheets (MAPA, 1999; 2001b).

Data on average rainfed and irrigated crop yield (*Y*) (kg/ha) at provincial level were taken from the Agro-alimentary Statistics Yearbook of the Spanish Ministry of Agriculture, Fisheries and Food (MAPA, 2007).

With regard to the crop parameters, as input data to CROPWAT, the crop coefficients in different crop development stages (initial, middle and late stage) were taken from FAO (Allen *et al*., 1998; FAO, 2003). The length of each crop in each development stage was obtained from FAO (Allen *et al*., 1998; FAO, 2003) when the climate region was specified; otherwise it was obtained from the work of Chapagain and Hoekstra (2004). The crop calendar was taken from the Spanish Ministry of Agriculture, Fisheries and Food (MAPA, 2001a). These data are also given at provincial level.

- Economic data

Data related to gross value added (GVA) were taken from the Guadiana River Basin Authority (CHG, 2008b). Gross Value Added is obtained by deducting intermediate consumption from final agricultural production. Thus gross value added is equal to net output or benefit to the farmer that can be used for the remuneration of productive factors. Nevertheless, in this study we will focus on the final economic agricultural production (total €). We consider that from a socio-economic point of view we have to consider not only the GVA. This is very important because the activity of farmers is mainly driven by it. However, the final economic agricultural production is very important for the region because it includes the total value of crops and in this number are included the elements necessary for the agricultural activity (except subsidies) as are the cost of labour, fertilizers, amortization of machinery, and so on.

Crop economic value (€/ton) for the year 2001 was obtained from the Spanish Ministry of Agriculture, Fisheries and Food (MAPA, 2007). We are aware, however, that prices may change significantly from one year to the other. These data are an average for the whole Spain. In the present report CAP subsidies were not included (CHG, 2008b).

- Hydrologic data

Data related to water origin (surface and groundwater) by agricultural region were taken from the Guadiana River Basin Authority (CHG, 2008b), which is based on the 1999 Agrarian Census of the National Statistics Institute (INE, 2007).

Green and blue crop consumptive water use (CWU, m^3/ha) data were estimated using the CROPWAT model (FAO, 2003) (see Methodology section). Data on blue water withdrawals (surface and ground water) were taken from the Guadiana River Basin Authority (2007). It is noteworthy that these withdrawals are not the same as the estimated water consumption or evapotranspirative demand.

Average global irrigation efficiency at provincial level was taken from the CHG (2008b). It depends on the type of irrigation technique used by the farmer. Localized or drip irrigation is the most efficient system with a 0.9 coefficient, followed by sprinkler irrigation with 0.7 and finally, surface flood irrigation (riego por gravedad o “a manta”) with 0.5.

Dual coefficients for vineyard, olive tree and tomato were estimated following SIAR (2008).

- Trade data

Data related to international trade at a provincial level were taken from ICEX (2008).

6. The Guadiana Basin (WP3.4) within the NeWater project

The Guadiana Basin is one out of seven basins that constitute the source of field data for the EU research project NeWater (New approaches to Adaptive Water Management under Uncertainty). The NeWater European project aims to develop new method and tools that facilitate the transition towards adaptive management of river basins integrating natural science, engineering and social science concepts and methodologies (NeWater, 2008). The seven case studies will serve to test the new approaches designed in the European project. All the seven basins are transboundary basins, that is, basins shared by two or more countries. The Guadiana Basin is included in the Albufeira Convention, a treaty between Spain and Portugal on the Luso-Spanish rivers, ratified in 1999 by both Parliaments.

The W.B. 3.4 case Study is the responsibility of the Complutense University of Madrid (UCM) together with three Scientific Partners: the Portuguese Instituto de Soldadura e Qualidade (ISQ), the Spanish Instituto Geológico y Minero de España (IGME) and Polytechnic University of Madrid (UPM). However, there has been a joint collaboration with other scientific partners of the NeWater project: Geological Survey of Denmark and Greenland (GEUS), Oxford University Centre for Water Management, Stockholm Environment Institute, Cemagref (Institut de recherche pour l'ingénierie de l'agriculture et de l'environnement).

7. Results

Since irrigated agriculture is the main blue water user in the Guadiana Basin (about 90% according to MIMAM, 2007), the present study mainly focuses on water use by this sector. First of all, two agricultural regions are studied in detail (Mancha and Don Benito) and then the whole river basin (Upper, Middle and Lower Guadiana plus TOP domain). Finally, the obtained green and blue crop water consumption values are compared with national and international studies.

7.1 Mancha and Don Benito analysis

A. Crop area

Mancha agricultural region is more than two times larger in area both total (4,700 km^2) and crop area (390,000 ha) than Don Benito (Table 1). Both of them have a significant crop area proportion devoted to irrigated agriculture (57% in the case of Don Benito and 38% in Mancha region) in comparison with the Spanish average which just amounts to 22% (MIMAM, 2007).

Table 1. Agricultural general values in Mancha and Don Benito agricultural regions in 2001. Total rainfall of 424 mm in Ciudad Real and 491 mm in Badajoz – average year.

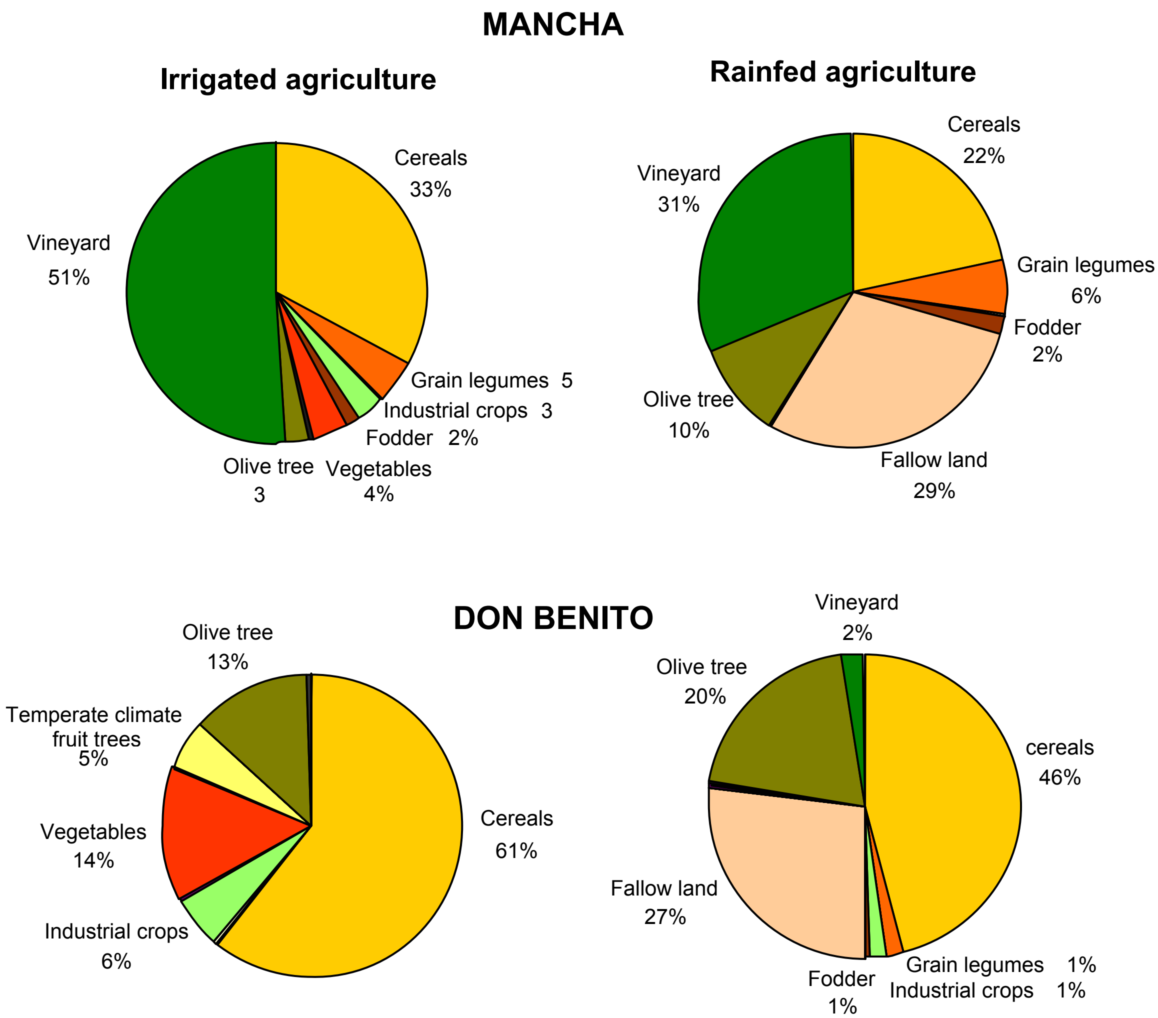
Agricultural region	Population[1]	Total area (km^2)	Crop area (ha)[1]			Irrigated area by irrigation system (ha)[2]				Average global irrigation efficiency[3]
			Total	Rainfed	Irrigated	Sprinkler	Localized	Surface flood	Total	%
Mancha	208,012	4,676	390,177	240,931	149,246	65,320	69,828	2,467	137,615	0.8

						(47%)	(51%)	(2%)	(100%)	
Don Benito	89,605	1,957	123,987	53,194	70,793	12,097 (22%)	12,785 (23%)	29,706 (54%)	54,588 (100%)	0.64

1 *Source*: CHG (2008b) for the year 2001.
2 *Source*: CHG (2008b) from data from 1999 Agricultural Census (National Statistics Institute, INE) and 1T sheets (Spanish Ministry of Agriculture, Fisheries and Food, MAPA) for the years 1989 and 1999. This may explain the difference between irrigated crop area (for 2001) and the total irrigated area (for 1989 and 1999).
3 Average global irrigation efficiency, as used here, depends on the type of irrigation technique used by the farmer. Localized or drip irrigation is the most efficient system with a 0.9 coefficient, followed by sprinkler irrigation with 0.7 and finally, surface flood irrigation (riego por gravedad o "a manta") with 0.5. From these efficiencies, an average irrigation efficiency is given at provincial level by the CHG (2008b).It is significant the great difference in the efficiency between the two regions. This is due to the predominant use of groundwater in La Mancha.

As shown in figure 5, in the year 2001 the area dedicated to each crop type varies in each region. Vineyards and cereals are the most important crops in Mancha, both in rainfed and irrigated agriculture. On the contrary, cereals and olive trees have to be highlighted in Don Benito and in particular vegetables in irrigated farming. In both cases it is noteworthy the high proportion of fallow land. After the Common Agricultural Policy reform (2003), however, vineyard and olive tree irrigated production has increased significantly in Spain (18% y 16% respectively) (MAPA, 2006). According to Garrido and Varela (2008) this is notable in Castilla- La Mancha Autonomous Community. It is expected that significant changes in crop distribution will continue to occur in the near future. This may be driven by diverse factors, some of them unexpected as the recent increase of cereals price, others due to technological advances such as the growing importance of the irrigation of olive-trees.

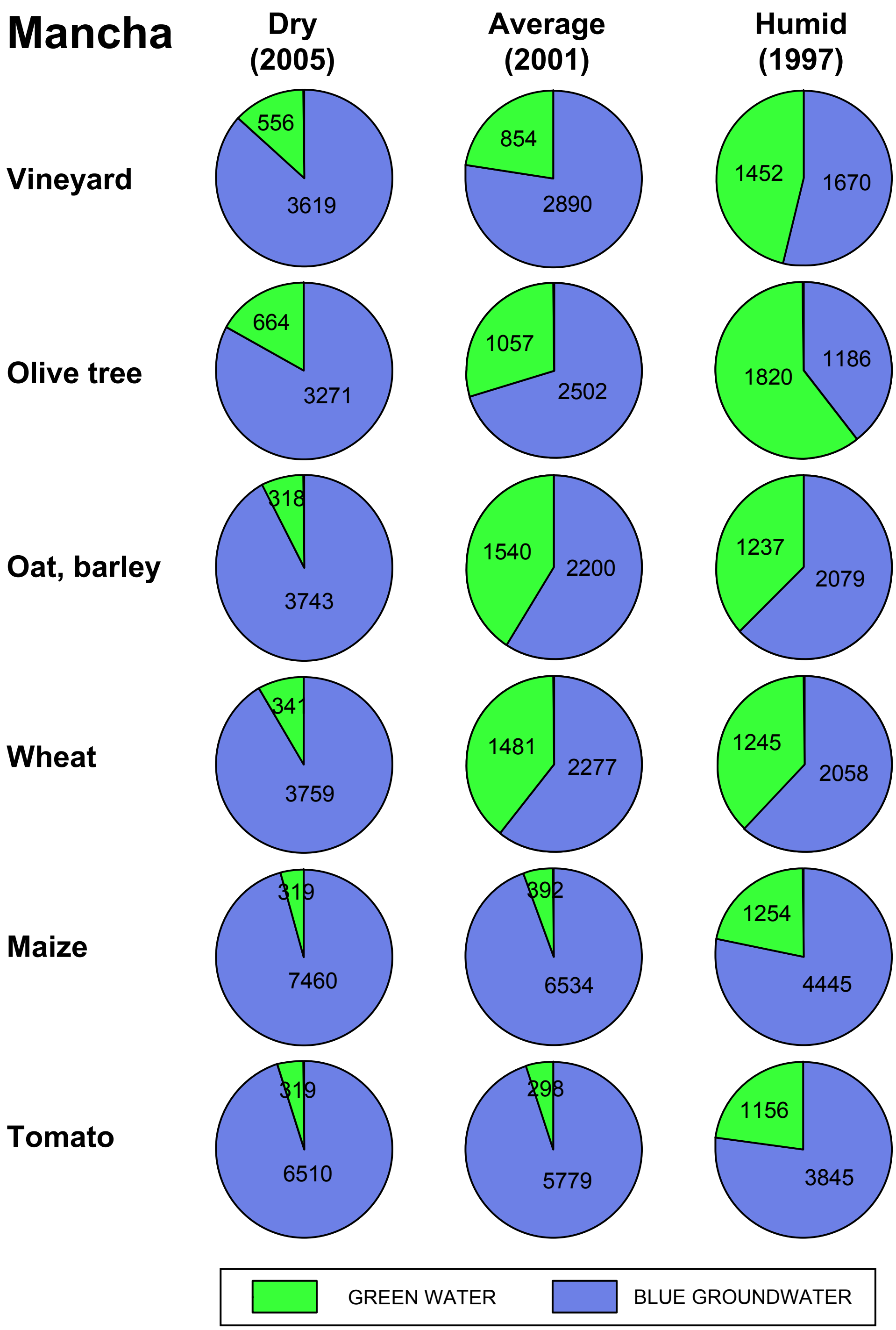
Figure 5. Crop area percentage of irrigated and rainfed agriculture in Mancha and Don Benito regions (average-year 2001). Showing crops occupying over 1% of land. Source: CHG (2008b)



B. Water consumption

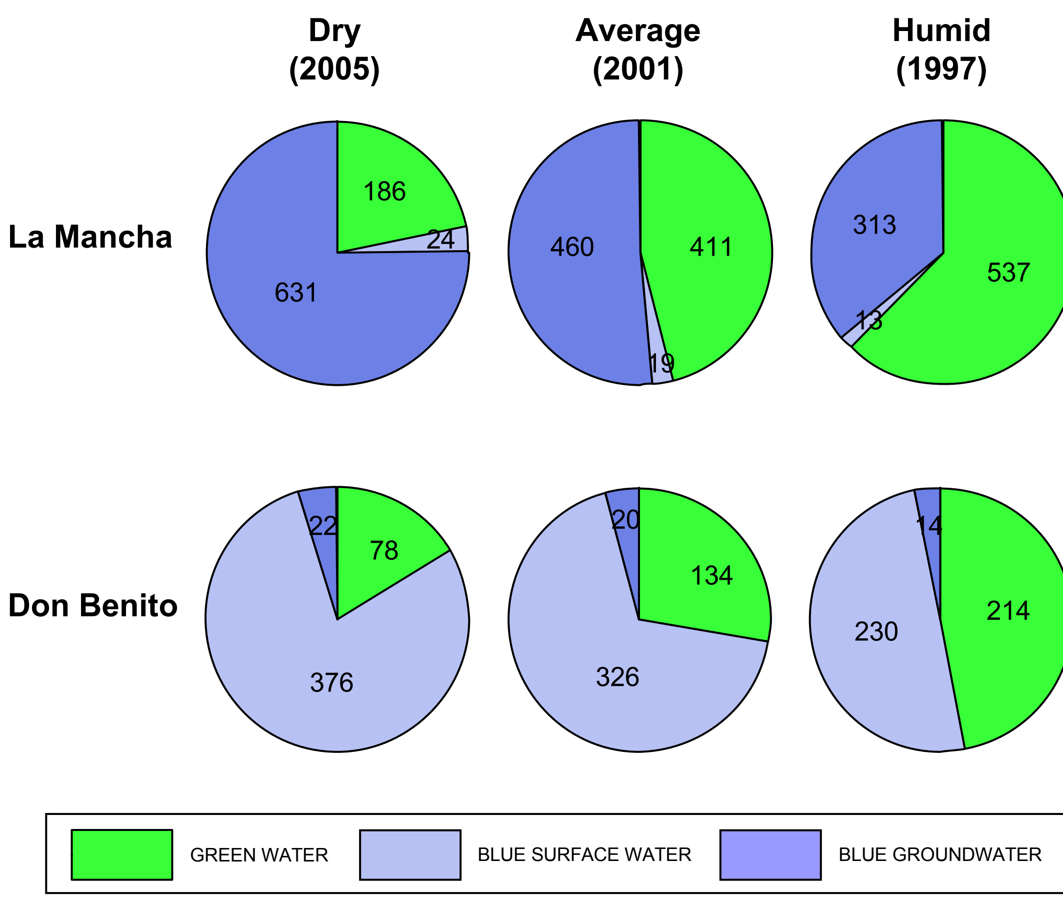
Concerning the crop consumptive water use (m^3/ha), we have initially considered that all the theoretical evapotranspirative crop demands are satisfied in irrigation. In the real world, these water demands in Don Benito agricultural region are probably satisfied. In Mancha agricultural region, however, which is overlying the Western Mancha Aquifer (Figure 2), this does not probably occur due to heavy political and administrative restrictions (Martínez-Santos, 2007). In 1987 the aquifer was legally declared overexploited by the Guadiana River Water Authority. Since then, in the overlying area there is a legal restriction of not using more blue water than 1200-2640 m^3/ha for herbaceous (depending on the planted area) and between 800-1000 m^3/ha for woody plants (mainly vineyards) (according to the rainfall) in 2007 (CHG, 2008b). As seen in figure 6 these numbers are lower than the theoretical water demands by the crops, estimated according to the previously explained method (using CROPWAT program).

Figure 6. Green and blue water consumption (m^3/ha) per crop and year in Mancha agricultural region assuming that evapotranspirative demands (using CROPWAT program) are completely satisfied, which is far away from the reality. Similar figures are obtained for Don Benito region. Source: Own elaboration.



When looking at the theoretical crop water requirements calculated for the 70% of the area of Mancha and 50% of Don Benito and extrapolated to the 100% of the cultivated area, interesting patterns emerge (Figure 7). It can be seen that the crop water requirements (CWR) are similar every year (about 800-900 Mm^3 in La Mancha and about 450 Mm^3 in Don Benito). As it might be expected, there are remarkable variations in the different types of rainfall years, being the blue water consumption higher in dry years and lower in humid years. In the case of Mancha agricultural region the dry year crop blue water requirements almost double the humid year ones.

Figure 7. Theoretical green and blue agricultural water consumption (Mm^3/year) in Mancha and Don Benito agricultural regions in a dry, average and humid year. The calculations are done with crops occupying 70% of the cultivated area in the case of La Mancha and 50% in Don Benito and adjusted to the 100% of the cultivated area. Source: Own elaboration.



As shown in Table 2, the theoretical crop water requirements (CWR), calculated for the 70% of the area of Mancha and 50% of Don Benito are extrapolated to the 100% of the cultivated area, are somewhat higher than the numbers given by the Water Authority for the same year (CHG, 2008b). There are, however, remarkable crop water requirement (CWR) variations in the different types of rainfall years as mentioned above.

As shown in table 2, total crop water requirement figures are closer to the total crop water supply numbers in Mancha than in Don Benito region. This is probably attributable to the high efficiency of irrigated agriculture in the former region. Localized and sprinkler irrigation systems predominate in Mancha, versus surface flood in Don Benito (Table 1).

Table 2. Total crop water supply and requirements in Mancha and Don Benito agricultural regions in 2001.

Agricultural region	Total water (Mm^3/year)					Water origin[4] (%)	
	Supply[1] (CHG, 2008b)	CWU_b[2] (CHG, 2008b)	CWU_b[3] (own elaboration)			Surface	Ground
Year	2001 Average	2001 Average	2001 Average	1997 Humid	2005 dry		
Mancha	450	360	479	325	656	0.04	0.96
Don Benito	380	243	346	244	398	0.94	0.06

1 Total crop water supply. Source: CHG (2008b)
2 Theoretical blue crop consumptive water use. Source: CHG (2008b) (Thornthwaite method)
3 Theoretical total blue crop consumptive water use in the Mancha agricultural region. It was calculated for 70% of the area for Mancha and 50% for Don Benito and adjusted to the 100% of the area assuming the same proportions. Own elaboration (see Methodology Section).
4 Surface and groundwater in volume percentage data, average value by agricultural region according to CHG (2008b).

Theoretical crop groundwater consumption data in Mancha region are compared with groundwater abstractions from the Upper Guadiana basin since they overlap in space (Table 3). As displayed in table 3, the water abstracted from the aquifers in the Upper Guadiana Basin, according to the Water Authority (CHG, 2008b) is not correlated with our theoretical crop water consumption in the Mancha agricultural region (Figure 7). This is probably due to the fact that many factors have an influence on the real water withdrawal, such as CAP payments not to irrigate, land-use changes, uncertainties due to illegal water users, insufficient control by the River Basin Authority and so on. Furthermore, we have to bear in mind that the area of Mancha region does not exactly match that of the whole Upper Guadiana basin. However, it is difficult to explain why the Water Authority considers that in the dry year 2005 the water abstraction (387 Mm^3) was smaller than in the humid year 1997 (417Mm^3). According to our method the theoretical evapotranspirative demand of blue water (practically all groundwater) was 631 Mm^3 (double than in the humid year)

Table 3. Water abstractions in the Upper Guadiana basin according to the Water Authority compared with the theoretical blue crop consumptive groundwater use in the Mancha agricultural region.

Year	water abstractions after CHG[1] Mm^3	Theoretical CWU_b[2] Mm^3
Humid - 1997	417	313
Average - 2001	387	460
Dry - 2005	387	631
Average 1980-2005	383	

1 Total water abstractions from the Upper Guadiana Basin. Source: CHG (2008b)
2 Theoretical blue crop consumptive groundwater use in the Mancha agricultural region. It was calculated for 70% of the area and adjusted to the 100% of the area assuming the same proportion. Own elaboration following FAO (2003).

C. Virtual water content (m^3/ton) in irrigated lands

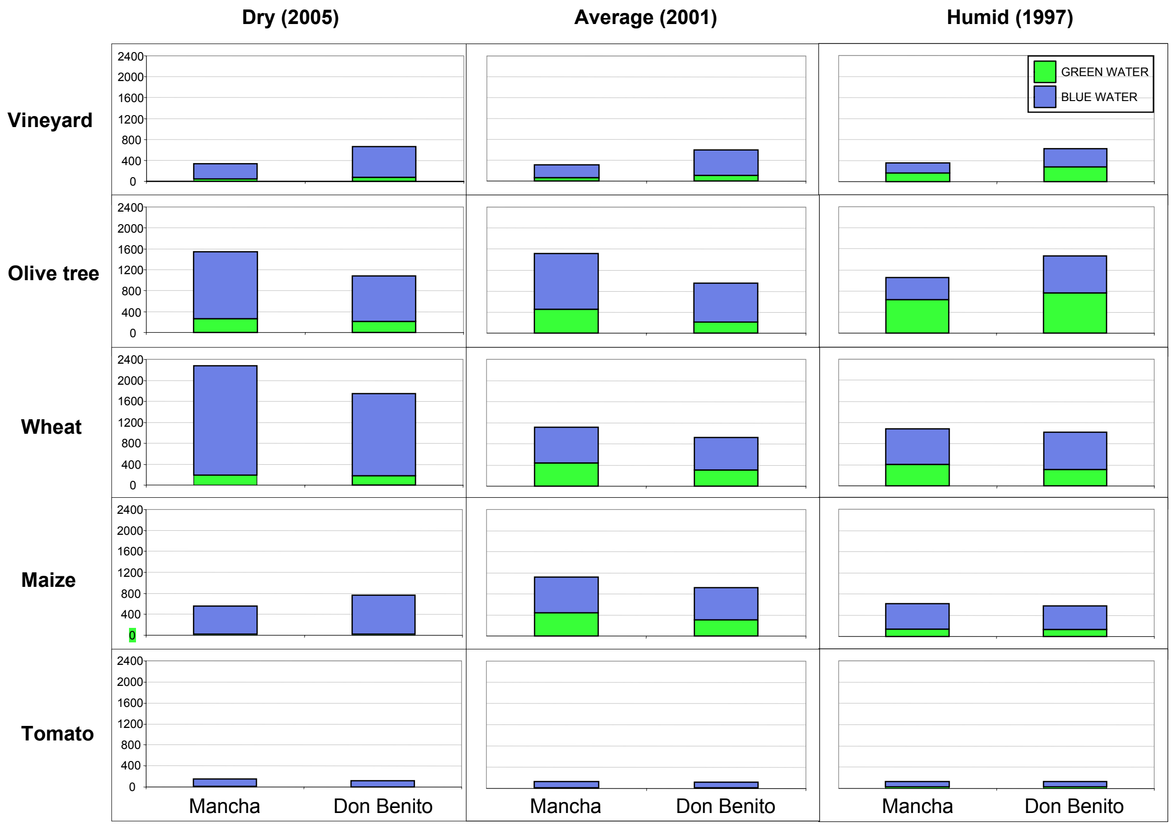
As shown in figure 8, it is noteworthy that, among the studied crops, olive trees and cereals show the highest blue virtual water contents in irrigated agriculture.

Most people consider that maize and vegetables are water-wasteful since in terms of m^3/ha these crops consume large amounts of water. Nevertheless, when looking at the virtual water content in m^3/kg these crops consume less water than it is generally believed. In fact, among the studied crops tomatoes exhibit the smallest virtual water content figures, probably due to the high yields they have.

Furthermore, when looking at food security issues, it could also be interesting to look at the nutritional value these crops provide (m^3/calorie) (Zimmer and Renault, 2003).

When comparing the virtual water contents of the different crops in Mancha and Don Benito these are quite similar. There are some differences, however, which may be due to the different evapotranspiration and yields these regions display and also to the approximate nature of our estimations.

Figure 8. Irrigated agriculture green and blue virtual content per crop and year in Mancha and Don Benito (m^3/ton).



Source: Own elaboration (see Appendices 1.2 and 1.3).

D. Agricultural economic productivity (€/ha)

As shown in table 4, and in accordance with Berbel (2007) and Hernández-Mora *et al.* (2001), agricultural economic productivity of irrigated agriculture is higher than that of rainfed agriculture. In our case this is true for any type of year (average, humid and dry). From a socio-economic perspective, irrigated agriculture not only provides a higher income, but also a safer income. This is due both, to the higher diversification it allows, and to the reduction of climate risks derived from rainfall variability (Comprehensive Assessment of Water Management in Agriculture, 2007). In our case, this security is provided by permanent water availability due to the huge surface water reservoirs in Don Benito and to the aquifer in Mancha (although the administrative restrictions decrease this security if the regulations are enforced, which is not clear).

On the whole, when comparing Mancha and Don Benito, vineyards have the highest economic productivity (€/ha) in Mancha both in rainfed and irrigated farming, while wheat, tomatoes and in particular irrigated olive-trees are more profitable in Don Benito. The olive tree economic productivity values (€/ha) are higher in Don Benito probably because of their higher yields in this region. It is difficult to discern, however, why this yield is so different in two regions with similar climate. We consider that it will be appropriate to get more information on the economic value of olive-trees. The fact is that apparently many farmers are changing their crops to irrigated olive-trees may mean that our present figures have to be updated (Garrido and Varela, 2008).

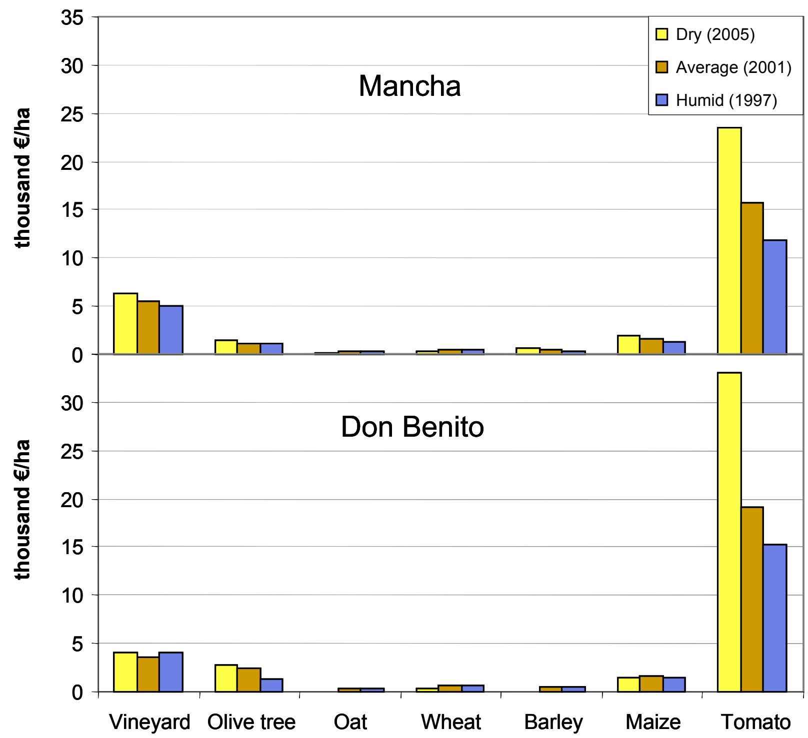
Table 4. Agricultural economic productivity (thousand €/ha) per crop and year in Mancha and Don Benito. These values do not include subsidies.

		Dry (2005)		**Average (2001)**		**Humid (1997)**	
	Crops	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
Mancha	Vineyard	2.8	6.4	1.8	5.5	2.8	5.0
	Olive tree	0.3	1.4	0.9	1.2	0.8	1.2
	Oat	0.1	0.1	0.1	0.4	0.1	0.4
	Wheat	0.1	0.3	0.2	0.5	0.1	0.5
	Barley	0.1	0.7	0.1	0.5	0.1	0.4
	Maize	0.1	1.9	1.0	1.6	0.2	1.3
	Tomato	-	23.5	-	15.7	-	11.8
	Weighted average	1.6	4.2	1.2	3.6	1.7	3.3
Don Benito	Vineyard	2.7	4.0	2.3	3.6	3.3	4.0
	Olive tree	0.6	2.8	0.8	2.5	0.5	1.3
	Oat	0.1	-	0.2	0.4	0.1	0.4
	Wheat	0.2	0.4	0.5	0.6	0.2	0.6
	Barley	0.2	-	0.4	0.5	0.2	0.5
	Maize	-	1.4	-	1.6	-	1.5
	Tomato	-	33.1	-	19.2	-	15.2
	Weighted average	0.4	7.8	0.6	5.2	0.4	4.0

Source: Own elaboration (see Appendices 1.2 and 1.3).

Regarding the tomato economic productivity, the drier the year the higher the productivity (Figure 9). This could be explained by the higher prices of tomatoes in the market in more arid years, at least in the case of the ones under study. Figure 9 and Table 4 clearly show the great differences in the economic productivity per hectare of the different crops in rainfed and irrigated agriculture. It seems that in the near future the main massive crops are going to be vineyards and olive-trees. Tomato and vegetables are in general more productive but are more related to the market changes and farmers in the region seem less prepared to cope with these uncertainties. Perhaps this will change in the future if a better commercial training is acquired by these farmers. The recent and spectacular increase in the prices of cereals does not seem to change the general outlook.

Figure 9. Economic productivity of irrigated crops in Mancha and Don Benito Agricultural regions (thousand €/ha).



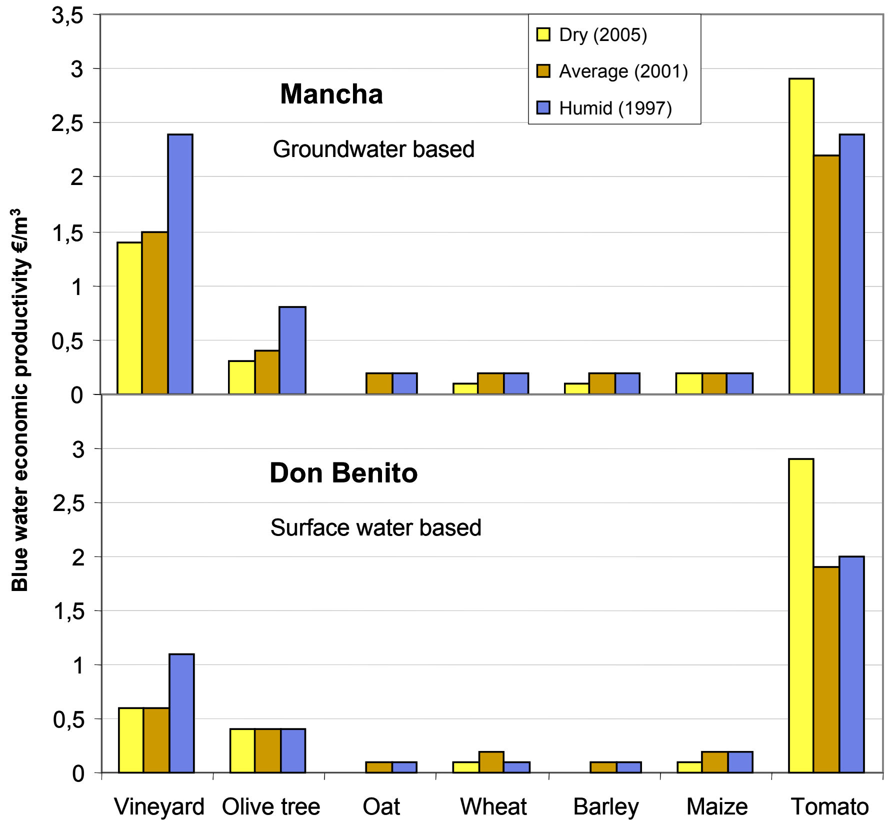
Source: Own elaboration (see Appendices 1.2 and 1.3).

E. Economic blue water productivity (€/m^3)

The economic water productivity analysis is one of the most important aspects of the present research. In arid or semiarid industrialized countries, such as the case of Spain, economic and environmental determinants are becoming more and more important and, either consciously or unconsciously, the old paradigm "more crops and jobs per drop" is shifting towards "more cash and nature per drop". Along these lines, groundwater plays a very relevant role in addressing this paradigm. In order to achieve this motto it is very important to know the economic water productivity of the different agricultural crops and differentiate the origin of water (groundwater use predominates in Mancha and surface water in Don Benito).

As it is shown in figure 10, economic water productivity varies depending on the type of crop. As expected, the crops with lower virtual water content and higher economic value present the highest economic water productivities, such as tomatoes (with around 2-3 €/m^3). This can be extended to other high value low water consumption vegetables in the region. Even with lower figures, vineyards (0.5-2.5 €/m^3) and olive trees (0.3-0.8 €/m^3) are the second and third most profitable crops in Mancha and Don Benito. This is probably the reason why vineyard and olive tree irrigated production has increased significantly in Spain (18% y 16% respectively) and in particular in Castilla- La Mancha Autonomous Community (MAPA, 2006). In the case of the vineyard economic water productivity in irrigated agriculture is higher in Mancha than in Don Benito. It is the opposite for the olive tree which is, in general, more productive in Don Benito. In any case, the water economic productivity is quite similar and rather low in these two continental regions. Low value crops are widespread, with the only exception of tomato, and other vegetables, which present higher economic values. In other regions with intensive horticultural production under plastic, probably the case of the former Guadiana TOP domain in Huelva, net productivities for irrigated agriculture can be as much as 50 times higher than when using surface water and as high as 12 €/m^3, such as the case of greenhouse cultivation using groundwater in Almeria (Vives, 2003).

Figure 10. Blue water economic productivity (€/m^3) concerning agricultural water supply by crop and year in Mancha and Don Benito.



Source: Own elaboration (see Appendices 1.2 and 1.3).

Table 5. Blue water economic productivity (€/m^3) concerning agricultural water supply by crop and year in Mancha and Don Benito. Source: Own elaboration (see Appendices 1.2 and 1.3).

Agricultural region	Crop	Economic water supply productivity (€/m^3) Dry year (2005)	Average year (2001)	Humid year (1997)
Mancha	Vineyard	1.4	1.5	2.4
	Olive tree	0.3	0.4	0.8
	Oat	0.0	0.2	0.2
	Wheat	0.1	0.2	0.2
	Barley	0.1	0.2	0.2
	Maize	0.2	0.2	0.2
	Tomato	2.9	2.2	2.4
Don Benito	Vineyard	0.6	0.6	1.1
	Olive tree	0.4	0.4	0.4
	Oat	-	0.1	0.1
	Wheat	0.1	0.2	0.1
	Barley	-	0.1	0.1
	Maize	0.1	0.2	0.2
	Tomato	2.9	1.9	2.0

Source: Own elaboration (see Appendices 1.2 and 1.3).

Overall, blue water economic productivity is higher in humid years. This is probably due to the fact that during humid years rainfall is higher and consequently farmers use less blue water (table 5). The only exception is the case of tomato production which is essentially based on blue water resources.

Water economic productivity (€/m^3) not only depends on the climatic conditions of each region and particularly on the yields, but also on the efficiency of the water use. Along these lines, as shown in Table 5, during the humid year (1997), the economic blue water productivity in relation to the crop water supply is higher in la Mancha region (mainly groundwater-based) than in Don Benito (mainly surface water-based) in all the studied crops. It is the same for the average (2001) and dry (2005) year, except for olive trees, which are more productive in Don Benito. Nevertheless, these differences in the economic water productivity are not so relevant as in other Spanish regions. We think that this is mainly due to the huge capacity of the surface water reservoirs that guarantee the irrigation water supply for irrigation in D. Benito. For instance, this is not the usual situation in Andalusia (see Llamas *et al*., 2001, pp. 151-152; Vives, 2003).

In line with existing data on groundwater use and its associated economic value, groundwater irrigated agriculture has a higher productivity when compared with irrigation using surface water (Hernández-Mora *et al.,* 2001). Some of the reasons that explain this higher productivity are the greater control and supply guarantee groundwater provides, which in turn allows farmers to introduce more efficient irrigation techniques; and the fact that users bear all private costs, thus paying a higher price per volume of water used than irrigators using surface water. This motivates them to look for more profitable crops that will allow them to maximize their return on investments and to use water more efficiently (Hernández-Mora *et al.,* 2007). This difference, in line with previous studies (Vives, 2003; Hernández-Mora and Llamas, 2001; Hernández-Mora *et al*., 2007), will probably be more prominent during severe drought periods since in Mancha region farmers can rely on secure groundwater sources. Nevertheless, as we have already mentioned, many are the factors that have an influence on blue water use, such as administrative restrictions or the Common Agricultural Policy support to investments for improving the state of irrigation infrastructure.

Consequently, and in line with Llamas (Llamas and Garrido, 2007), the estimated data for irrigated agriculture in Mancha and Don Benito regions show that, groundwater is usually more productive than surface water resources, even if the Middle Guadiana basin is one of the most regulated river basins in Spain.

F. Agricultural trade

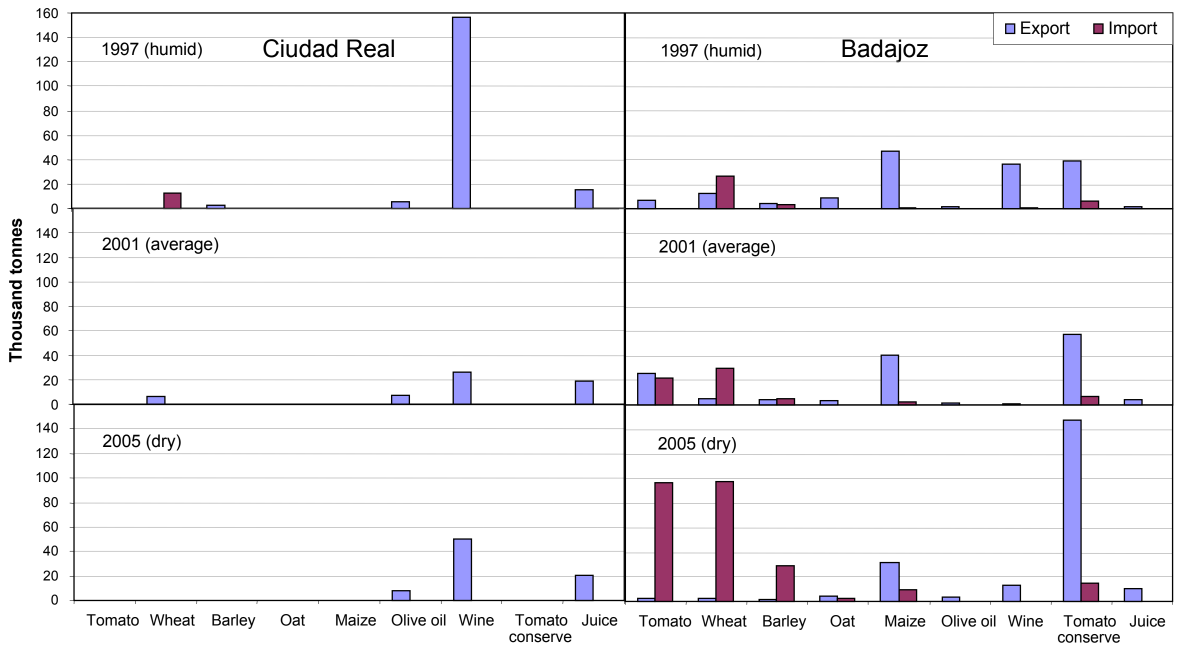
In most Water Footprint studies the food trade among the different zones has a great relevance. In our case this relevance is smaller and the lack of disaggregated data only allows a very preliminary analysis.

Data provided in this section are taken from ICEX (2008), which provides international trade data at a provincial level. Interprovincial trade, therefore, is not taken into account as we have not been able to find the adequate data.

Concerning trade in tonnes, it is noteworthy that Ciudad Real, comprising Mancha, is a net exporter as a whole, and in particular of wine (Figure 11). Badajoz, including Don Benito, is a net canned-tomato exporter, while importing other commodities such as fresh tomatoes or wheat. It is has to be highlighted the increase of tomato and wheat imports in the analysed dry year in this province (figure 11). These imported tomatoes are probably transformed and re-exported. Extremadura, and in particular Badajoz, is the main industrial tomato exporter in Spain.

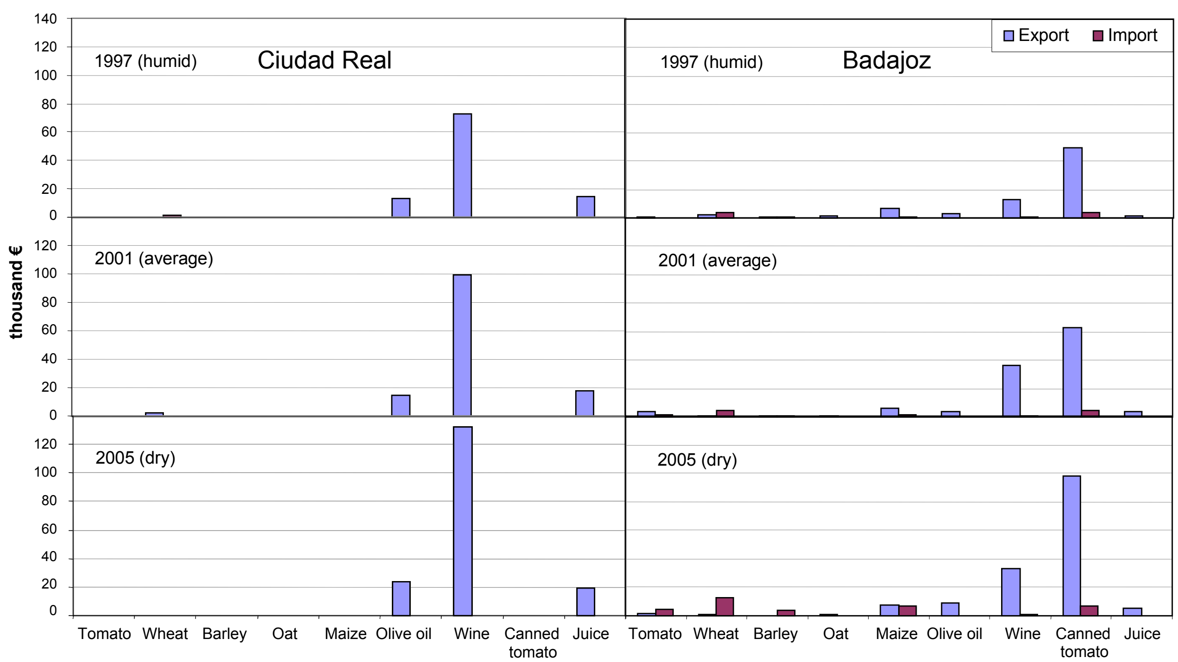
Similar patterns can be seen in figure 12 for international trade in economic terms, being Ciudad Real a net wine exporter both in tons and euros while Badajoz industrial tomato exporter in both senses. This is in line with crop production data in both Mancha and Don Benito agricultural regions, where vineyards and fresh tomatoes are mainly grown respectively.

Figure 11. Agricultural commodity export and import in thousand tonnes from Ciudad Real and Badajoz during the years 1997 (Humid), 2001 (average) and 2005 (dry).



Source: ICEX (2008)

Figure 12. Agricultural commodity export and import in thousand euros from Ciudad Real and Badajoz during the years 1997 (Humid), 2001 (average) and 2005 (dry).



Source: ICEX (2008)

7.2. Guadiana Water Footprint

As seen in the methodology chapter, and in order to complete the analysis, the Guadiana river basin has been divided in four areas (Upper, Middle, Lower Guadiana and TOP domain).

The Guadiana basin has an area of about 67,000 km^2 (83% in Spain and 17% in Portugal). The climate is semiarid, with an average precipitation of about 450 mm/year and average annual temperature of 14-16 ºC (CHG, 2008a; INAG, 2007).

When comparing the Guadiana basin Gross Value Added (GVA) with national figures for the different sectors, the agricultural sector represents a value of 8.4 % of the national total, having both agriculture and livestock similar shares. Agriculture of the TOP domain represents 1.6 % of the national GVA, representing the livestock just a small amount (0.3 %). Concerning the manufacture industrial sector GVA, both in the Guadiana basin and TOP domain, it is not relevant in comparison with the total national, representing 1.99 % and 0.45 % of the total national respectively. These figures show the relevance of agriculture in these areas in comparison with other Spanish regions where industry and tourism are more important.

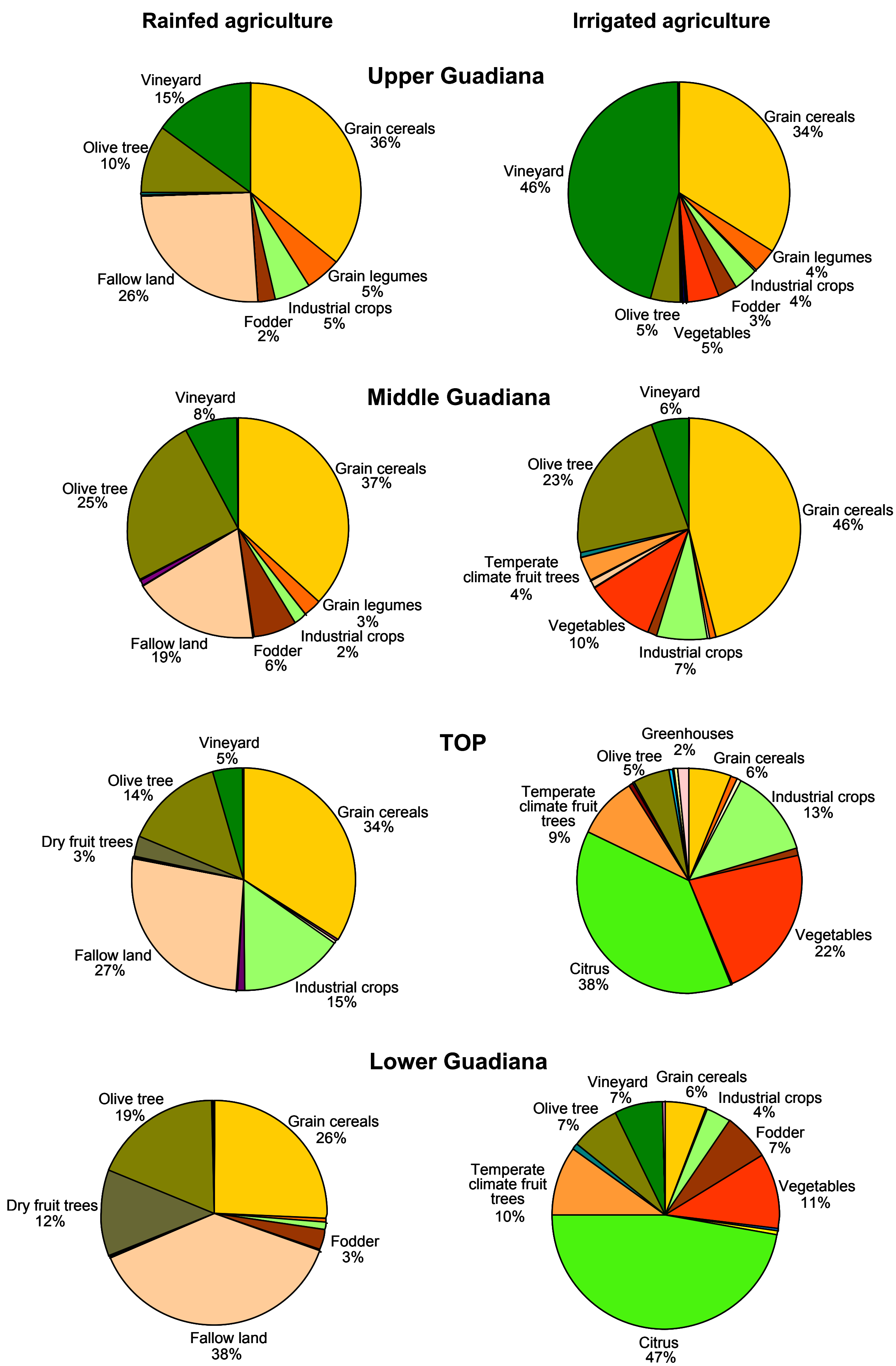
A. Crop area

The Spanish Guadiana river basin crop area is 26,000 km^2, which is about 47% of the total area. As a whole, in the basin, 19% of the crop area is devoted to irrigated agriculture. This proportion is similar to the Spanish average which amounts to 22% (MIMAM, 2007).

As shown in figure 13, the area dedicated to each crop type varies in each Guadiana section in the year 2001 (average precipitation). When looking at the rainfed agriculture similar crops are grown in the different Guadiana sections, highlighting cereals, olive trees and vineyards. Concerning irrigated agriculture, in general, cereals, vineyards and olive trees dominate in the Upper and Middle Guadiana basins, whereas citrus trees and vegetables in the Lower Guadiana and TOP domain. In all the cases it is noteworthy the high proportion of fallow land. After the Common Agricultural Policy reform (2003), however, vineyard and olive tree irrigated production has increased significantly in Spain

(18% y 16% respectively) (MAPA, 2006). According to Garrido and Varela (2008) this is notable in Castilla- La Mancha Autonomous Community. It is expected that significant changes in crop distribution will continue to occur in the near future due to different causes, such as the increase in cereal prices.

Figure 13. Percentage of areas of irrigated and rainfed crops in the Upper, Middle, Lower Guadiana and TOP domain (average-year 2001). Showing crops occupying over 1% of land. Source: CHG (2008b).


Rainfed agriculture
Irrigated agriculture
Upper Guadiana
Vineyard 15%
Grain cereals 36%
Olive tree 10%
Fallow land 26%
Grain legumes 5%
Industrial crops 5%
Fodder 2%
Grain cereals 34%
Vineyard 46%
Grain legumes 4%
Industrial crops 4%
Fodder 3%
Olive tree 5%
Vegetables 5%
Middle Guadiana
Vineyard 8%
Grain cereals 37%
Olive tree 25%
Grain legumes 3%
Industrial crops 2%
Fallow land 19%
Fodder 6%
Vineyard 6%
Olive tree 23%
Grain cereals 46%
Temperate climate fruit trees 4%
Vegetables 10%
Industrial crops 7%
TOP
Vineyard 5%
Olive tree 14%
Grain cereals 34%
Dry fruit trees 3%
Fallow land 27%
Industrial crops 15%
Greenhouses 2%
Olive tree 5%
Grain cereals 6%
Temperate climate fruit trees 9%
Industrial crops 13%
Vegetables 22%
Citrus 38%
Lower Guadiana
Olive tree 19%
Grain cereals 26%
Dry fruit trees 12%
Fodder 3%
Fallow land 38%
Vineyard 7%
Grain cereals 6%
Industrial crops 4%
Olive tree 7%
Fodder 7%
Temperate climate fruit trees 10%
Vegetables 11%
Citrus 47%

B. Water use and consumption: total and by the agricultural sector

Total Water Use

As in most arid and semiarid regions, in the Guadiana river basin the main green and blue water consuming sector is irrigation, with about 95% of total water consumption in the basin as a whole (Table 6). The following main blue water user is urban water supply with less than 5% of the water applied for irrigation. If we consider that most urban water returns to the system, it can be said that irrigation consumptive uses are more than 95% of all the uses. However, the security of this supply is extremely relevant from a political and economic point of view. Concerning the Andalusian part (Lower Guadiana and the so-called TOP domain), irrigation consumes a lower water proportion, of about 75-80%, which account for the increase of the urban water supply. The industrial sector, even if it is the smallest water user, represents the highest economic value (GVA). Agriculture is also a significant economic activity in the Guadiana river basin, being the most important share of the GVA after the industrial sector (Table 6). Thus, even if urban and industrial uses have an obvious economic and social relevance, agriculture, as the highest water consumer in the basin, is the key to water resources management in the area.

Concerning rainfed and irrigated farming in the whole basin excluding TOP domain, total rainfed area is more than five times the irrigated area (2,100x10^3 and 400x10^3 hectares respectively) (Appendix 2). Rainfed systems consume about 55% of the total water consumed by the agricultural sector (Table 6) and use green water (i.e. rainfall) that has a lower opportunity cost compared to the blue water use (i.e. irrigation) (Chapagain *et al.*, 2005). Even if significantly smaller in extension, irrigated agriculture produces more tonnes and euros than rainfed agriculture (Appendix 2A and 2C).

Table 6. Internal Water Footprint of the Guadiana Basin (year 2001)

TOTAL GUADIANA[1]							
Population	**Internal Water Footprint**[6]	Green Mm^3/year	Blue Mm^3/year	Total Mm^3/year	Per capita m^3/cap/year	GVA[7] million €	Water economic productivity €/m^3
1,417,810	Agricultural	2,212	1,827	4,039	2,849	1,096	0.60
	Livestock		22	22	16	286	12.74
	Urban		130	130	91	128[8]	0.99[9]
	Industrial		20	20	14	1,557	77.90
	Total	2,212	1,999	4,211	2,970	3,068	1.53

UPPER GUADIANA[2]							
Population	**Internal Water Footprint[6]**	Green	Blue	Total	Per capita	GVA[7]	Water economic productivity
		Mm³/year			m³/cap/year	million €	€/m³
636,721	Agricultural	1,286	928	2,214	3,478	599	0.65
	Livestock		5	5	8	131	25.05
	Urban		55	55	86	54[8]	0.99[9]
	Industrial		12	12	19	929	77.04
	Total	1,286	1,000	2,286	3,591	1,714	1.71

MIDDLE GUADIANA[3]							
Population	**Internal Water Footprint[6]**	Green	Blue	Total	Per capita	GVA[7]	Water economic productivity
		Mm³/year			m³/cap/year	million €	€/m³
672,534	Agricultural	905	886	1,792	2,664	413	0.47
	Livestock		13	13	20	124	9.30
	Urban		65	65	96	64[8]	0.99[9]
	Industrial		6	6	9	485	78.82
	Total	905	970	1,876	2,789	1,086	1.12

TOP[4]							
Population	**Internal Water Footprint[6]**	Green	Blue	Total	Per capita	GVA[7]	Water economic productivity
		Mm³/year			m³/cap/year	million €	€/m³
341,080	Agricultural	74	77	151	444	205	2.66
	Livestock		1	1	3	10	8.57
	Urban		38	38	112	38[8]	0.99[9]
	Industrial		8	8	24	554	68.62
	Total	74	125	199	583	807	6.47

LOWER GUADIANA[5]							
Population	**Internal Water Footprint[6]**	Green	Blue	Total	Per capita	GVA[7]	Water economic productivity
		Mm³/year			m³/cap/year	million €	€/m³
62,213	Agricultural	21	13	33	535	45	3.54
	Livestock		1	1	20	9	7.42
	Urban		7	7	106	7[8]	0.99[9]
	Industrial		1	1	16	82	80.76
	Total	21	22	42	677	143	6.63

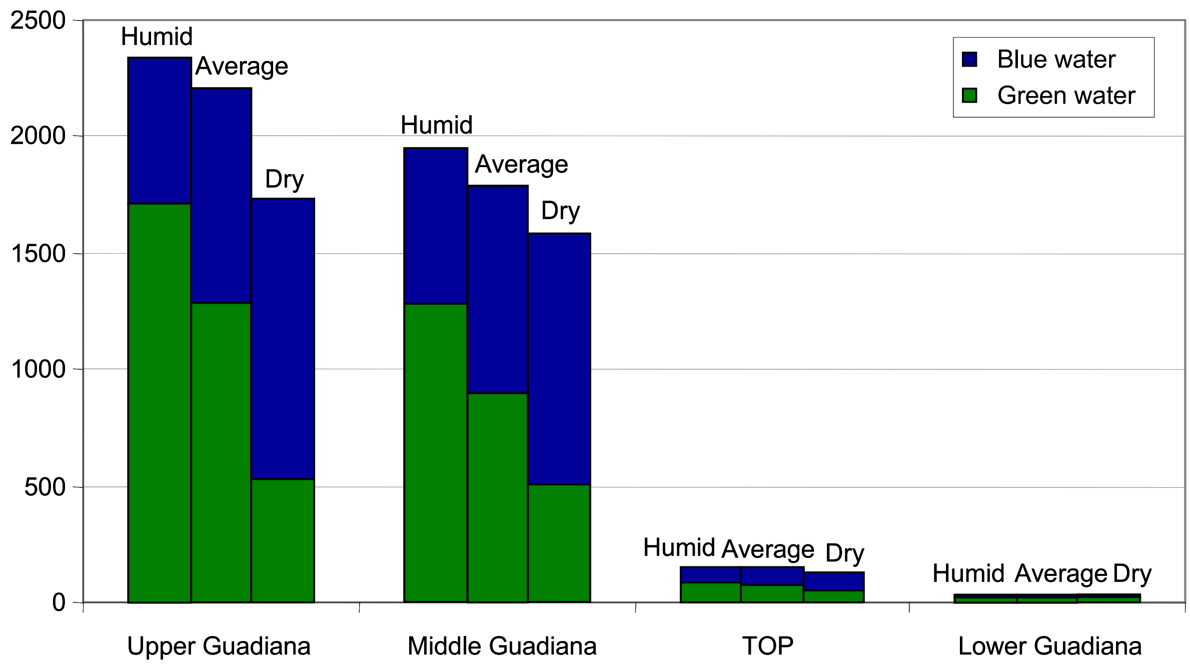
1 The Total Guadiana region includes the whole Guadiana river basin excluding the TOP domain. It is not the average of the Upper and Middle Guadiana.
2 The Upper Guadiana includes a fraction of Castilla-La Mancha Autonomous region.
3 The Middle Guadiana includes a fraction of Extremadura (Badajoz and Cáceres).
4 In line with CHG (2008b), TOP region is the Tinto, Odiel and Piedras river basin complementary region.
5. TheLower Guadiana region includes the fraction of the basin in Huelva.
6 The internal water footprint is the volume of water used from domestic water resources to produce the goods and services consumed by the inhabitants of a country. It is the sum of the total water volume used from the domestic water resources in the national economy minus the volume of virtual water export to other countries insofar related to export of domestically produced products (Chapagain and Hoekstra, 2004). The present study, however, will not subtract exports as data are not easily available.
7 Source: CHG (2008b)
8 Estimated with data from MIMAM (2007): 0.99 €/m³ for urban water supply and sanitation in the Guadiana river basin.

9 Source: MIMAM (2007)

Agricultural water consumption

As shown in figure 14, when taking into account rainfed and irrigated water consumption, crop water requirements are somewhat higher in the humid year. As it might be expected, there are remarkable variations in the green and blue water proportions in years with different rainfall patterns, being the blue water consumption higher in dry years and lower in humid years. While logically the green water consumption shows the opposite pattern.

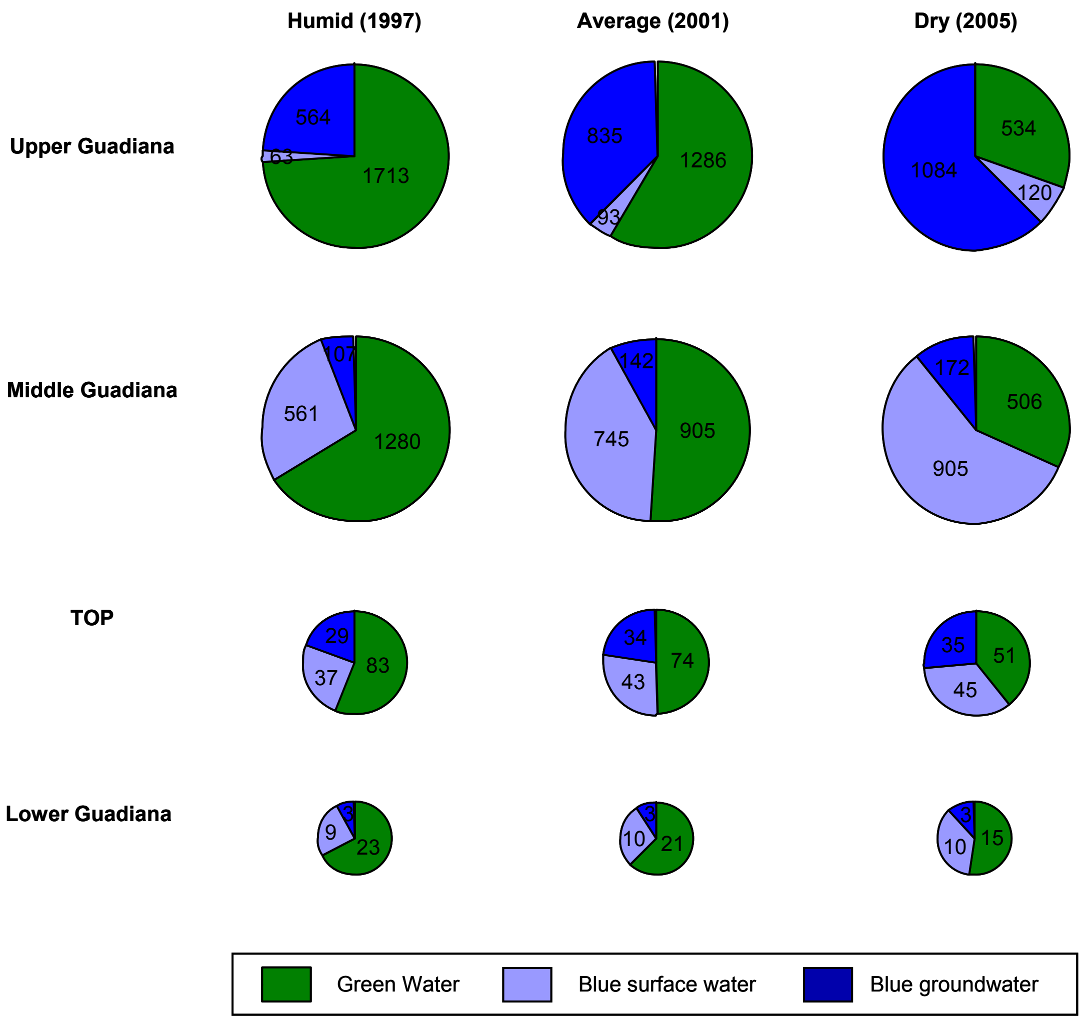
Figure 14. Theoretical green and blue agricultural water consumption (Mm^3/year) in the Upper, Middle, Lower Guadiana and TOP domain a dry (2005), average (2001) and humid year (1997). Source: Own elaboration.



The blue water consumption in the Upper Guadiana basin is mainly based on its groundwater resources, whereas the Middle Guadiana basin uses its surface water resources, mainly coming from large surface water reservoirs (Figure 15). The Lower Guadiana basin and TOP domain combine both ground and surface water strategies.

Once again, it is noteworthy the relevance of groundwater use in the Upper Guadiana in comparison to the Middle Guadiana.

Figure 15. Theoretical green and blue (surface and ground) agricultural water consumption (Mm^3/year) in the Upper, Middle, Lower Guadiana and TOP domain a dry (2005), average (2001) and humid year (1997). The size of the circle is proportional to the volume of water. Source: Own elaboration.



C. Virtual water content in irrigated lands (m^3/ton)

The virtual water analysis establishes the amount of water required by specific crops and it differs considerably among crop and climate types. For instance, Spain has a comparative advantage over most of the other European countries in the production of Mediterranean crops (such as vegetables, citrus fruits, vineyards or olive oil). It is also important to determine whether the water used proceeds from blue (i.e. irrigation) or green water (i.e. rainfall), and whether the blue water is surface or ground water.

Figure 16 provides an overview of the virtual water content of irrigated crops (m^3/ton) in the different sections of the Guadiana basin in the different rainfall years. As shown in this figure, it is noteworthy that, among the studied crops, industrial crops (such as sunflowers), grain legumes, grain cereals (1,000-1,300 m^3/ton) and olive trees (about 1,000-1,500 m^3/ton) show the highest virtual water contents in irrigated agriculture. In humid years, however, olive trees are mainly based on green water resources. As previously mentioned, until recently, olive trees (and vineyards) were typical rain-fed crops. However, in last years the irrigated area seems to be significantly increasing for both crops.

It is widely believed that maize and vegetables are water-wasteful since in terms of m^3/ha these crops consume large amounts of water. Nevertheless, when looking at the virtual water content in m^3/kg these crops consume less water than it is generally believed. In fact, among the studied crops vegetables (100-200 m^3/ton) exhibit the smallest virtual water content figures, probably due to the high yields they have.

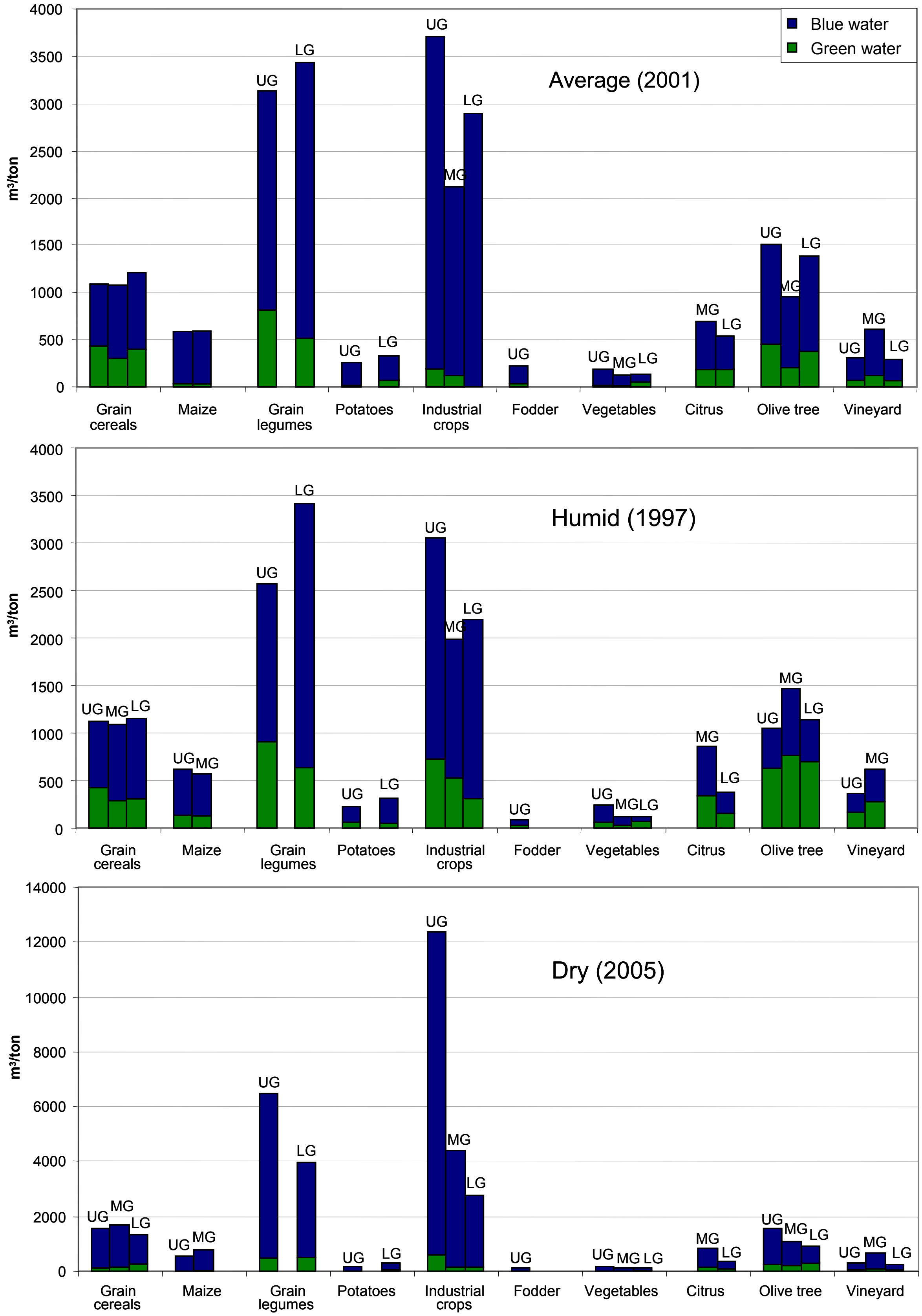
Finally, vineyards have intermediate virtual water contents, of about 300-600 m^3/ton.

Despite the semiarid nature of the Guadiana basin, in the Upper and Middle Guadiana basin irrigated grain cereal production is widespread in the year 2001. Even if vineyards and olive trees are the most widespread crop in the basin during the year 2001, aside from cereals. Two reasons may explain this trend. First, vineyards are significantly water-efficient (in fact, vineyards are traditionally considered dryland crops) and second, irrigated vineyards provide quite high economic revenue per hectare.

In the Lower Guadiana basin and TOP domain, on the other hand, irrigated citrus trees and vegetables account for most part of the irrigated area and represent the highest total economic values in this region. What occurs in these two small areas of our study is a general situation in other coastal areas of Andalusia (Hernández-Mora *et al*. 2001; Vives, 2003).

The economic value of agricultural commodities is an important aspect. For example, many farmers have moved from water-intensive and low economic value crops to water-extensive and higher economic value crops. Alfalfa has been substituted by grapevine or olive trees (Llamas, 2005). According to Llamas (2005) the motto “more crops and jobs per drop” should be replaced by “more cash and nature per drop”. Nevertheless, there is still a long way to go to achieve this motto in the Upper and Middle Guadiana basins. In the Lower Guadiana and TOP domain it has been partly achieved, at least on its first half.

Figure 16. Irrigated agriculture green and blue virtual content per crop and year in the different Guadiana sections: UG: Upper Guadiana, MG: Middle Guadiana, LG: Lower Guadiana and TOP domain in different rainfall years (m^3/ton). Source: Own elaboration.

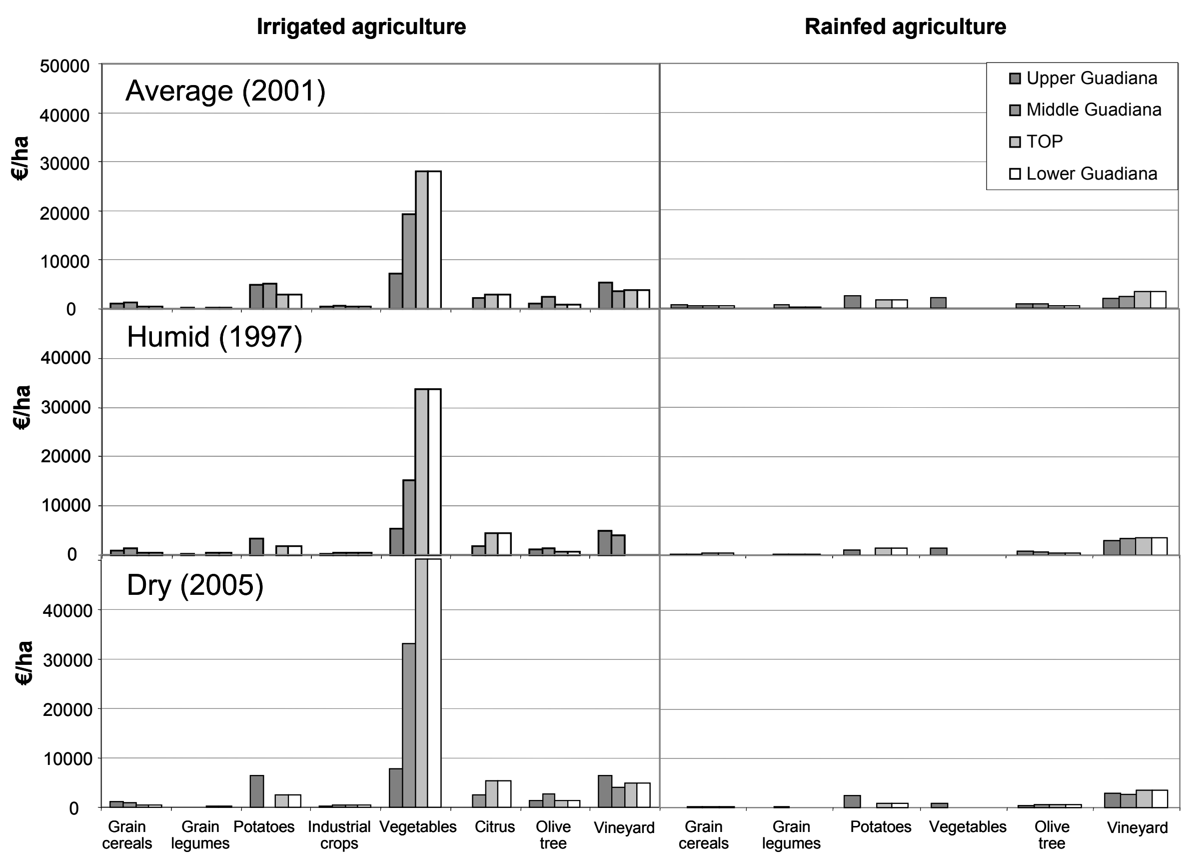

Average (2001)
Humid (1997)
Dry (2005)
Blue water
Green water
m³/ton
Grain cereals
Maize
Grain legumes
Potatoes
Industrial crops
Fodder
Vegetables
Citrus
Olive tree
Vineyard
UG
MG
LG

D. Agricultural economic productivity (€/ha)

As it is widely known, agricultural economic productivity of irrigated agriculture is higher than that of rainfed agriculture (Berbel, 2007; Hernández-Mora *et al.,* 2001; MIMAM, 2007). In the case of the Guadiana basin this is true for any type of year (average, humid and dry) (Figure 17).

Concerning the agricultural economic productivity per crop of irrigated agriculture, vegetables have the highest revenues per hectare (5,000-50,000 €/ha). Followed by vineyards (about 4,000-6,000 €/ha), citrus in the Andalusian section (3,000-5,000 €/ha), potatoes (2,000-6,000 €/ha) and olive trees (about 1,000-3,000 €/ha). Finally grain cereals, grain legumes and industrial crops have productivities of less than 1,000 €/ha.

Figure 17. Economic productivity of irrigated and rainfed agriculture per hectare by crop type in the different Guadiana sections in different rainfall years (€/ha). Source: Own elaboration.



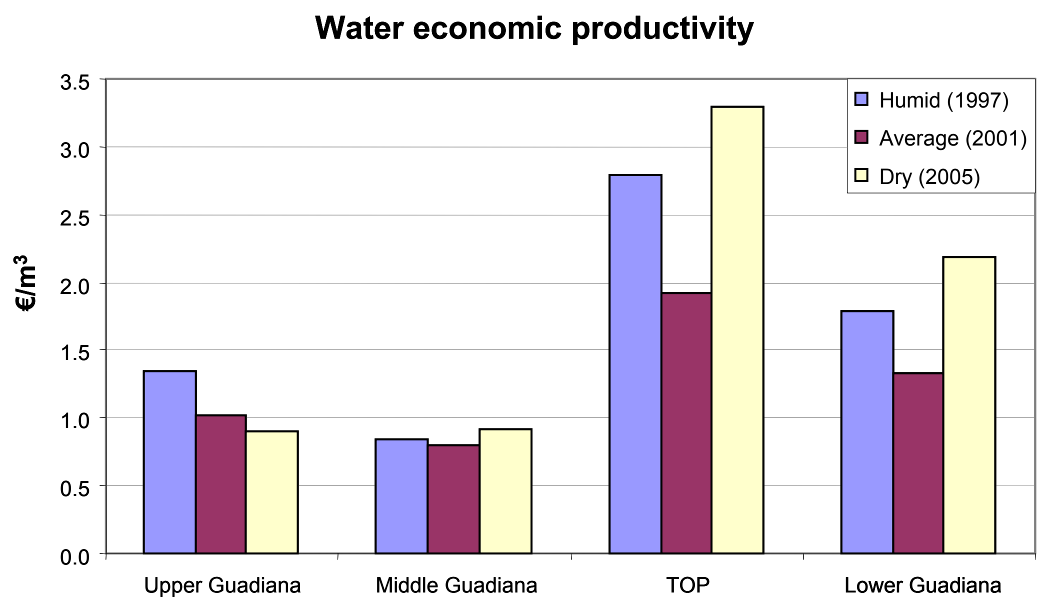
E. Economic blue water productivity (€/m^3)

The agricultural total water economic productivity has been calculated in two different ways: using GVA (CHG, 2008b) (Table 6) and using crop economic value (MAPA, 2002) (Figure 18). In both cases the highest value per cubic meter is obtained in the Andalusian part (including the Lower Guadiana and TOP domain), due to the high economic value of the vegetables, which are widespread in the region.

According to Llamas and Martínez-Santos (2005), most probably high value crops are watered with groundwater resources or combining ground and surface water. For instance, Hernández-Mora *et al*. (2001) show that, in Andalusia (in a study considering almost one million irrigated hectares), agriculture using groundwater is economically over five times more productive and generates almost three times the employment than agriculture using surface water, per unit volume of water used. This difference can be attributed to several causes: the greater control and supply guarantee that groundwater provides, which in turn allows farmers to introduce more efficient irrigation techniques and more profitable crops; the greater dynamism that has characterized the farmer that has sought out his own sources of water and bears the full costs of drilling, pumping and distribution; and the fact that the higher financial costs farmers bear motivates them to look for more profitable crops that will allow them to maximize their return on investments (Hernández-Mora *et al*., 2001). Surface and groundwater distinction, therefore, should be taken into account in order to achieve an efficient allocation of water resources. Furthermore, in line with previous studies in arid and semi-arid regions (Garrido *et al*., 2006; Hernández Mora *et al*. 2001; Vives 2003), the social (jobs/m^3) and economic (€/m^3) value of groundwater irrigation generally exceeds that of surface water irrigation systems. Agricultural water economic productivity was thus expected to be higher in groundwater based areas.

Along these lines, the Lower Guadiana basin and TOP domain, with a joint surface and groundwater use, have the highest agricultural water economic productivities because they predominantly grow cash crops. The groundwater based Upper Guadiana basin has intermediate values, whereas the surface water based Middle Guadiana shows the lowest water economic productivities. Nevertheless, Upper and Middle Guadiana present similar values in dry years. Probably, this small difference is due on the one hand, to the water irrigation security provided by the existing large surface water reservoirs in the Middle Guadiana; and, on the other, because the use of groundwater in the Upper Guadiana basin has serious legal and political restrictions, at least in theory.

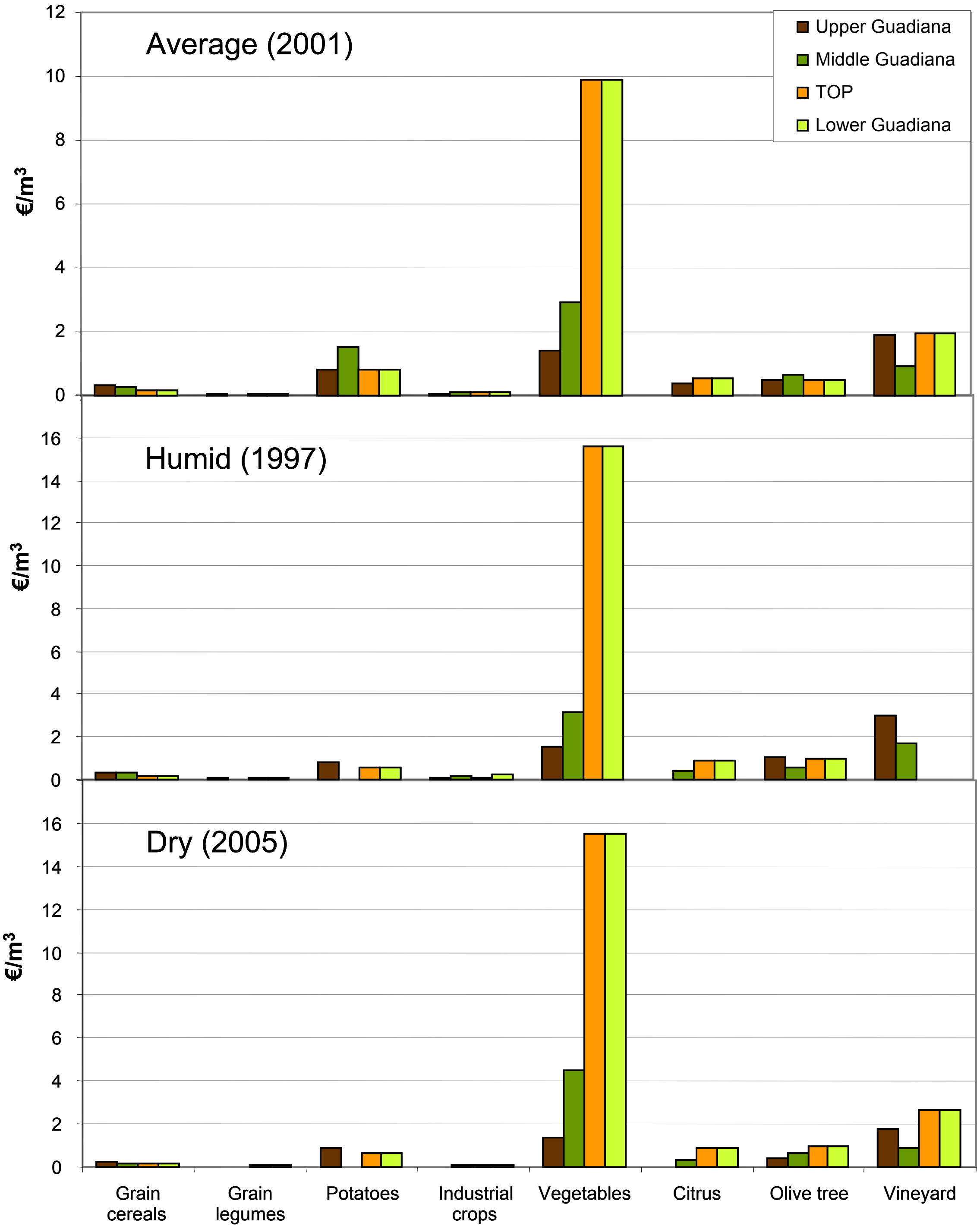
Figure 18. Total blue water economic productivity (€/m^3) concerning agricultural water consumption by year in the Upper, Middle and Lower Guadiana and TOP domain. Source: Own elaboration.



The water economic productivity analysis can be very useful in order to identify possible water uses not justified in economic efficiency terms and achieve an efficient allocation of water resources.

According to MIMAM (2007), average productivity of blue water used in irrigated agriculture in Spain is about 0.44 €/m^3. When looking at the productivity per crop type in the Guadiana basin (Figure 19), vegetables (including horticultural and greenhouse crops) present the highest economic value per water unit (amounting to 15 €/m^3 in the Andalusian part: Lower Guadiana and TOP domain). These numbers are similar to the figures estimated by Vives (2003) for greenhouse cultivation using groundwater in Almeria, which amount to 12 €/m^3. With lower values vineyards (1-3 €/m^3), potatoes (0.5-1.5 €/m^3), olive tree (0.5-1 €/m^3) and citrus trees (0.3-0.9 €/m^3) show intermediate values. Finally, with remarkably lower values, grain cereals, grain legumes and industrial crops display an average productivity of less than 0.3 €/m^3. These data clearly show that the problem in the Guadiana basin is not water scarcity but the use of water for low value crops. Once again, the policy in the near future has to be to more cash per drop.

Figure 19. Blue water economic productivity (€/m^3) concerning agricultural water consumption by crop and year in the Upper, Middle and Lower Guadiana and TOP domain. Source: Own elaboration.



F. Agricultural trade

The international trade data provided in this section are given at a provincial level as more disaggregated data were not found (ICEX, 2008). The main provinces of each river basin section have been analysed: Ciudad Real for the Upper Guadiana, Badajoz for the

Middle Guadiana and Huelva for the Lower Guadiana and TOP domain. Part of the data concerning Ciudad Real and Badajoz were already considered in section 7.1 F.

Concerning trade in tonnes, euros and virtual water, it is noteworthy that Ciudad Real is a net exporter, mainly of wine, and barely imports any commodity (Figure 20). During the studied period this province has relied on its own food production without depending on global markets. This has been probably at the cost of using its scarce water resources.

In relation to Badajoz, is a net canned-tomato exporter, while importing other commodities such as cereals. It has to be highlighted the increase in cereal imports in drier years (Figure 21).

Huelva also imports virtual water intense commodities, such as cereals, whereas exports low virtual water content fruits (Figure 22). The drier the year the higher the cereal imports. In hydrologic terms, cereal virtual water imports save 1015 Mm^3 in Huelva, whereas vegetable exports just uses 100 Mm^3. Even if in terms of tonnes and water consumption cereal imports remarkably surpass fruit exports, in economic terms fruit exports are much more important than cereal imports.

Virtual water imports, and in particular cereal imports, play a role in compensating for the water deficit and providing water and food security in the Middle Guadiana and Andalusian part (Lower Guadiana and TOP domain). For these regions, however, the underlying motivation of importing food (virtual water) is probably hardly a pursuit of comparative advantage, but to fill the domestic shortfall of food supply and to maintain social stability.

According to the World Water Council (2004) one can only speak of virtual water trade if conscious choices are made in water and environmental management policies whether or not to make water available or to release pressure on the domestic water resources by importing goods that else would have consumed much of the domestic water resources available. To make conscious choices, the elements of choice and the players involved in virtual water trade have to be made visible. Allan (2001) states that virtual water trade is so successful because it is invisible and is applied beyond the general political debate. However, invisibility may lead to postponement of necessary reforms by politicians as imports can be regarded as 'secret reserves' that might bail out in the short run (Warner, 2003).

Finally, the concept of virtual water trade could be very relevant for this region. Local planning and regional collaboration incorporating the notion of virtual water trade could result in exchange of goods, diversification of crops, diet awareness creation or crop replacement actions.

Figure 20. Agricultural commodity export and import in thousand tonnes, million euros and million cubic metres from Ciudad Real during the years 1997 (Humid), 2001 (average) and 2005 (dry). Source: Own elaboration based on ICEX (2008) and Chapagain and Hoekstra (2004) data.

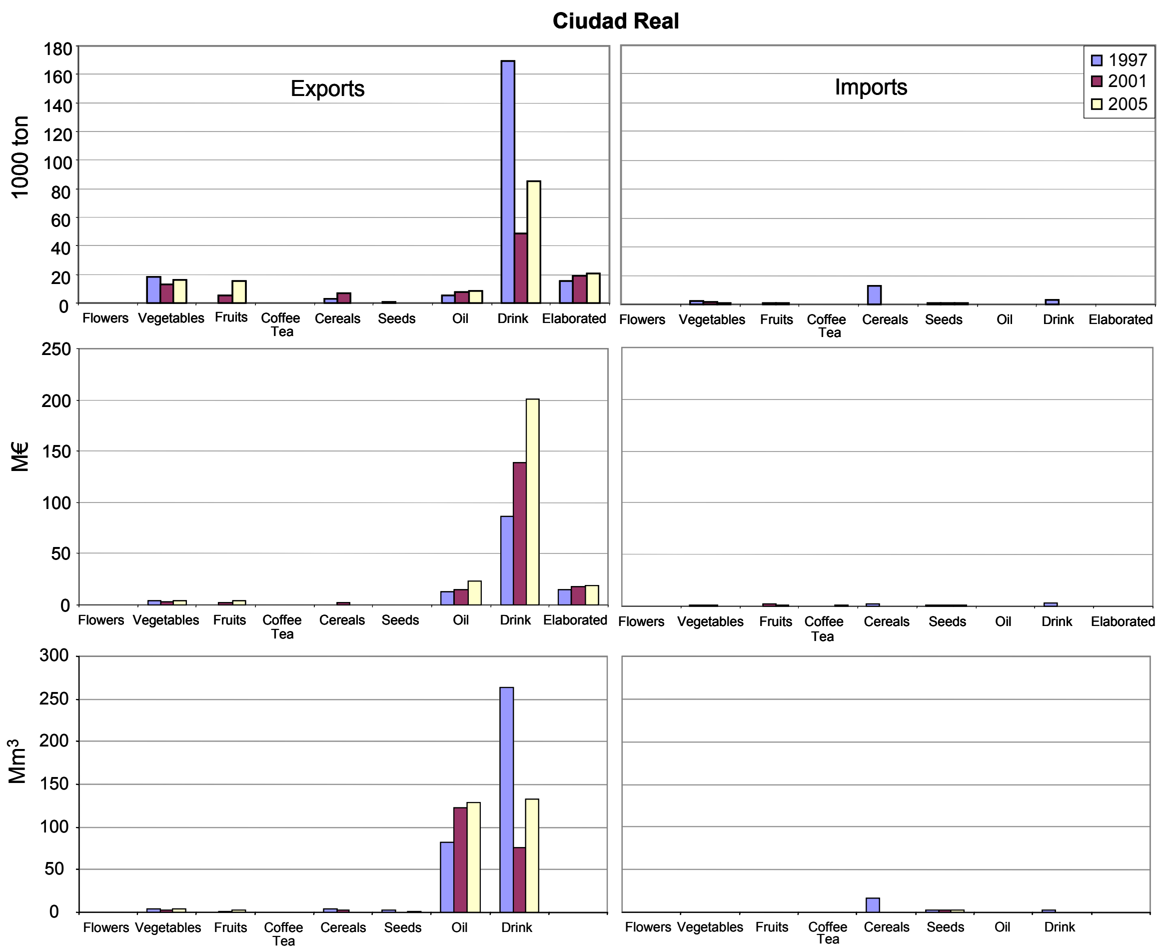


Figure 21. Agricultural commodity export and import in thousand tonnes, million euros and million cubic metres from Badajoz during the years 1997 (Humid), 2001 (average) and 2005 (dry). Source: Own elaboration based on ICEX (2008) and Chapagain and Hoekstra (2004) data.

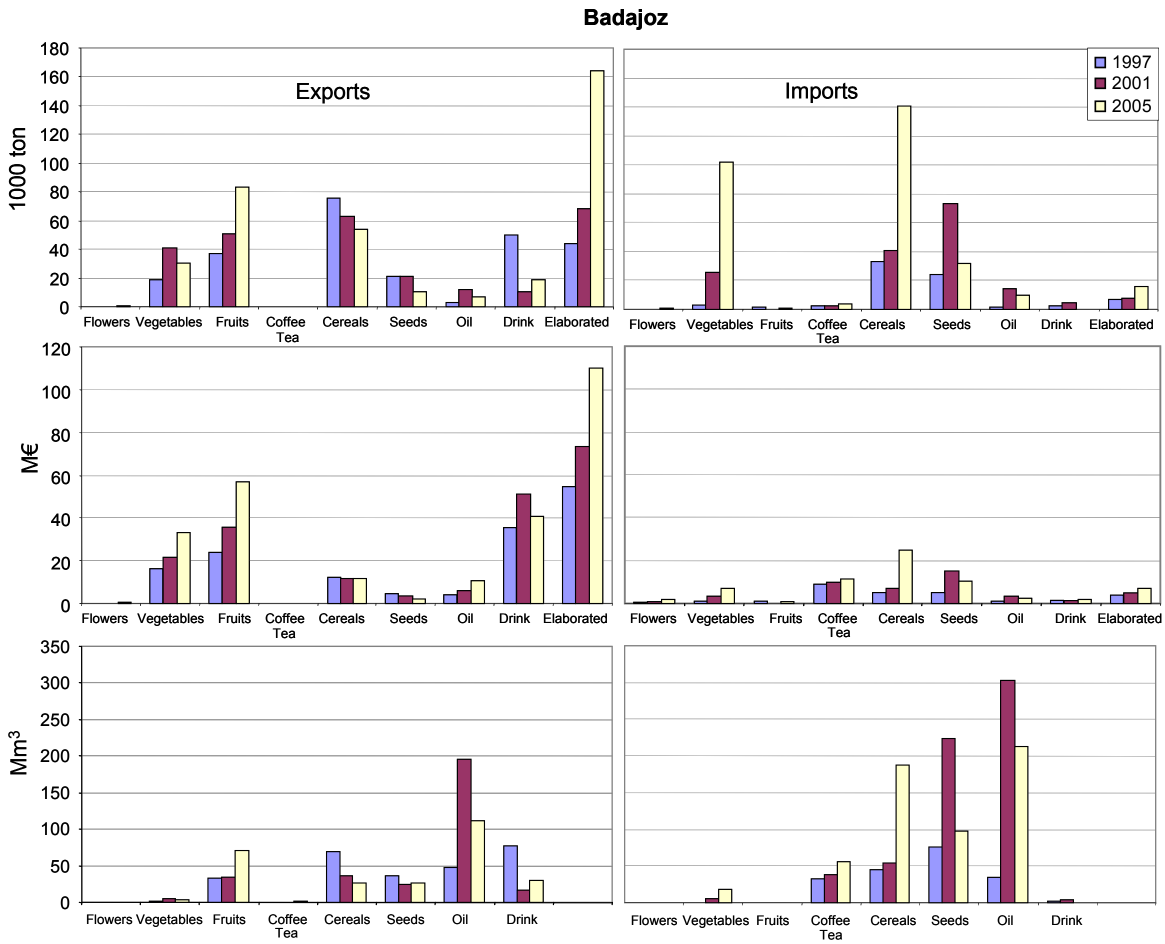
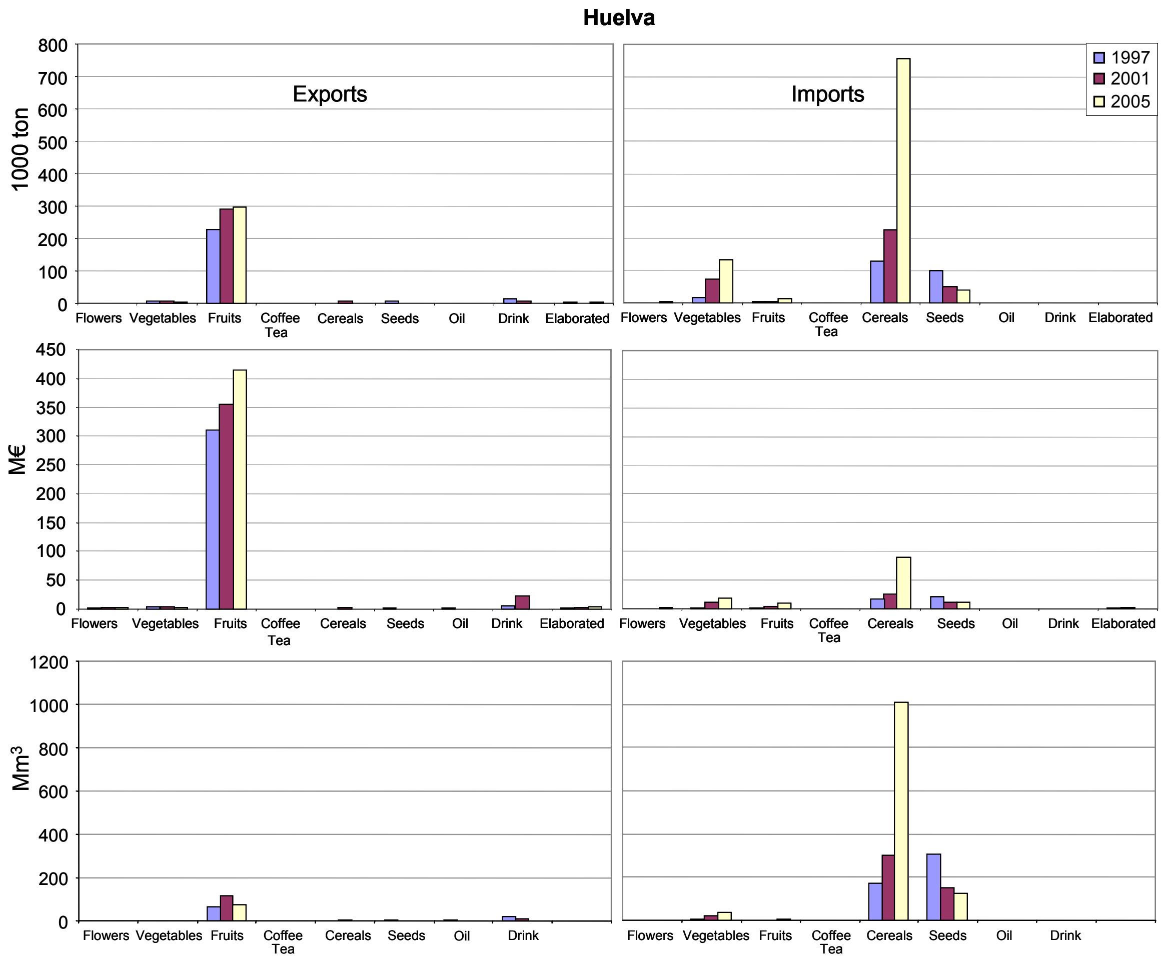


Figure 22. Agricultural commodity export and import in thousand tonnes, million euros and million cubic metres from Huelva during the years 1997 (Humid), 2001 (average) and 2005 (dry). Source: Own elaboration based on ICEX (2008) and Chapagain and Hoekstra (2004) data.



7.3. Why this study should be considered as a first approximation to reality?: A review of crop water consumption estimates by various experts

The present study should be taken as a very interesting but rough approximation to the reality. In tables 7 and 8 green and blue water requirements of the analysed crops by various sources are presented.

When comparing the green water consumption data with other sources, there is a remarkable disparity derived from the methodology in use (Table 7). The present green crop water use numbers, based on FAO Penman-Monteith equation and CROPWAT model, are higher than figures given by the ITAP (2008), based on the FAO Penman-Monteith equation and an estimation of effective irrigation as 70% of total rainfall. Furthermore, small changes in planting and harvest dates entail big changes in crop water use figures (m^3/ha). This could explain these differences.

With regard to the different rainfall years, as expected, there are notable differences depending on the type of year, being lower in dry years (Table 7).

When looking at the theoretical blue water consumption values, the present research results do not seem to differ significantly from other sources (Table 8). As shown in table 7, wheat and other cereals as a whole consume great amounts of blue water whereas their economic value in the markets is very low. Olive tree and vineyard blue water requirements vary depending on the source but they are generally somewhat lower than those of the cereals.

In our opinion, even if these data are a first approximation, they clearly show that the water policy in the Guadiana Basin can and should apply progressively the motto “more cash and nature per drop”.

Table 7. Green water crop consumptive use values (m^3/ha) by different sources.

MANCHA	Present study (Aldaya and Llamas, 2008)[1]			Rodríguez (2008)[2]	ITAP (2008)[3]	Chapagain and Orr (2008)[4]
Year	Humid 1997	Average 2001	Dry 2005	2001	2001 (2003)[5]	?
Location	La Mancha			Castilla-La Mancha	Albacete	Ciudad Real
Water consumption	CWU_g[6]			CWU_g[6]	CWU_g[6]	CWU_g[6]
Vineyard	(1452)[7]	(854)[7]	(556)[7]	352	237	
Olive tree	(1820)[7]	(1057)[7]	(664)[7]	665	231	
Oat	1237	1540	318	700		
Wheat	1245	1481	341	867	318	
Barley	1237	1540	318	799	319	
Maize	1254	392	319	594	267	
Tomato	(1156)[7]	(298)[7]	(319)[7]			880

1 Calculations based on FAO Penman-Monteith equation using CROPWAT model (FAO, 2003) and a time step of 5 days.
2 Calculations based on FAO Penman-Monteith equation and a time step of 30 days.
3 Calculations based on FAO Penman-Monteith equation, effective irrigation estimated as 70% of total rainfall.
4 Calculations based on FAO Penman-Monteith equation using CROPWAT model (FAO, 2003) and a time step of 5 days.
5 2001data for wheat, barley and maize, while 2003 data for vineyard and olive tree.
6 Green consumptive water use (m3/ha)
7 Estimated applying a location coefficient for localized irrigation (ET0 * Kc * Kl) following SIAR (2008).

Table 8. Blue water crop consumptive use values (m^3/ha) by different sources.

MANCHA	Present study (Aldaya and Llamas, 2008)[1]			Rodríguez (2008)[2]	CHG (2008b)[3]	CHG (2008b)[4]	CHG (2005)[5]	Tarjuelo (2000)[6]	PEAG (CHG, 2008c)[7]	ITAP (2008)[8]	SIAR (2008)[9]	Chapagain and Orr (2008)[10]	Hoekstra and Chapagain (2004)[11]
Year	Humid 1997	Average 2001	Dry 2005	2001	2001	2001	2001-2004	1974-1998	?	2001 (2003)[12]	2001 (2007)[13]	?	1997-2001
Location	La Mancha			Castilla-La Mancha	La Mancha	Ciudad Real	Western Mancha	Ciudad Real	Western Mancha	Albacete	La Mancha	Ciudad Real	Spain
Water consumption	CWU_b[14]			CWU_b[14]	CWU_b[14]	CWU_b[14]	CWU_b[14]	CWU_b[14]	CWU_b[14]	CWU_b[14]	CWU_b[14]	CWU_b[14]	CWU[15]
Vineyard	(1670)[16]	(2890)[16]	(3619)[16]	3977	2690	3678	1516	2000-2500	3678	2388	1693		6622
Olive tree	(1186)[16]	(2502)[16]	(3271)[16]	3991	1930		2153			2186			7350
Oat	2079	2200	3743	3801	(2350)[17]	2306			2306				2830
Wheat	2058	2277	3759	2533		2583	3342	2842	2583	3902	2403		3070
Barley	2079	2200	3743	3976		2999	2690	2759	2999	2630	1880		2831
Maize	4445	6534	7460	7347		7014	8117	5174	7014	7262	7604		6116
Tomato	(3845)[16]	(5779)[16]	(6510)[16]		(3510)[18]						5705	3730	3165

1 Calculations based on FAO Penman-Monteith equation using CROPWAT model (FAO, 2003) and a time step of 5 days.
2 Calculations based on FAO Penman-Monteith equation and a time step of 30 days.
3 Calculations based on Thornthwaite method.
4 Calculations based on FAO Penman-Monteith equation. Do not consider deficit irrigation strategies. These data may vary with respect to other CHG data calculated according to Thornwaite method.
5 Calculations following SIAR.
6 Calculations based on FAO Penman-Monteith equation, and 25 year climate series. For the vineyard deficit irrigation recommendations are followed (riego deficitario controlado, RDC).
7 Source: Tragsatec and MIMAM. Do not consider deficit irrigation strategies.
8 Calculations based on FAO Penman-Monteith equation, effective irrigation estimated as 70% of total rainfall.
9 Calculations based on FAO Penman-Monteith equation using deficit irritation for trees.
10 Calculations based on FAO Penman-Monteith equation using CROPWAT model (FAO, 2003) and a time step of 5 days.
11 Calculations based on FAO Penman-Monteith equation using CROPWAT model (FAO, 2003).
12 2001data for wheat, barley and maize, while 2003 data for vineyard and olive tree.
13 2001 data for every crop except for tomato (industry) in 2007.
14 Blue consumptive water use (m^3/ha)
15 Total consumptive water use (including green and blue) (m^3/ha)
16 Estimated applying a location coefficient for localized irrigation ($ET_0 * K_c * K_l$) following SIAR (2008).
17 Value for grain cereals
18 Value for vegetables

8. Conclusions

1. The present virtual water and water footprint analysis, both hydrological and economic, of the Guadiana river basin, provides very interesting results. This analysis however is a first approximation. The calculated theoretical crop water requirements somewhat differ from other authors. There is an outstanding dispersion of data amounting to 100% in certain cases that may be originated by the different methodologies. On the whole, our crop water requirements are based on FAO Penman-Monteith equation and CROPWAT model, whereas figures given by the CHG (2008b) and SIAR (2008) are based on the Thornthwaite and FAO Penman-Monteith equation respectively. In other cases, the uncertainties on some basic data are related to political issues. One example of this is the lack of acceptable accuracy on the inventory of water users and rights, and on the irrigated area by legal and illegal water wells.

2. As in most arid and semiarid regions, in the Guadiana river basin the main green and blue water consuming sector is irrigation, with about 95% of total water consumption in the basin as a whole. Concerning the blue water economic productivity, however, urban water supply and industry values are higher than the corresponding value in agriculture. The multifunctional value of agriculture, however, has to be taken into account.

Rainfed agriculture has a high relevance in the Guadiana basin in terms of total hectares. Agricultural economic productivity (ton/ha) and total production (ton/year) of rainfed agriculture, however, are notably lower than that of irrigated agriculture. Thus, even if less in extension, irrigated agriculture produces more tonnes and euros than rainfed agriculture. This economic and social fact explains the political relevance of groundwater irrigation in the Upper Guadiana basin.

3. In any case it is noteworthy that the PEAG (Plan Especial del Alto Guadiana, Upper Guadiana Special Plan) and the Guadiana draft Water Plan (to be sent to Brussels in 2009 in line with the WFD) values, which are 350 Mm^3 and 290 Mm^3, respectively, for all the crops in the Western Mancha (CHG, 2008b), are significantly lower than the values obtained by the present study for the whole Mancha, 479 Mm^3. The cause of this difference

is still to be debated, but it is a crucial issue for the achievement of the PEAG, which has an official budget of 5,500 million Euros (about 8 US$ billion) in twenty years. This budget is higher than the cancelled water transfer from the Ebro River to the Mediterranean coastal zones. If the current general difficult economic atmosphere continues in Spain, many experts are doubtful about its implementation.

4. As a whole, high virtual-water low-economic value crops are widespread in the analysed Upper and Middle Guadiana regions. For instance, cereals exhibit virtual water values of 1,000-1,300 m^3/ton or even higher in dry years. On the other hand, maize and vegetables (mainly tomato and melons) present the smallest values with around 600 and 100-200 m^3/ton respectively, due to their high yields.

5. One of the most important contributions of the present report is the analysis of the economic productivity of blue water use for the different crops. In the Upper and Middle Guadiana basin, it seems to range between 0.1-0.2 €/m^3 for low cost cereals and 1.5-4.5 €/m^3 for vegetables. These values are relatively small in comparison with the ones obtained in the Andalusian region (Lower Guadiana and TOP domain). In this region, for vegetables (including horticultural and crops under plastic) using jointly surface and groundwater resources, this value can amount to 15 €/m^3.

Even with lower figures, vineyards (1-3 €/m^3) and olive trees (0.5-1 €/m^3) seem to be profitable crops. As a matter of fact it is widely known that farmers are currently changing their production to vineyards and olive trees. It could be interesting to examine these trends in the near future.

6. Nevertheless, we can not fall into the simplification that all the water that is not used for vegetables or trees is wasted water. Factors such as risk diversification, labour or other environmental, social, economic and agronomic reasons have to be taken into account in order to find a balance. The major environmental challenge of agriculture is the preservation of the environment without damaging the agricultural sector economy. The amount of crops and the employment generated in the whole Guadiana basin is producing "more crops and jobs per drop". The aim now is to achieve the paradigm “more cash and

nature per drop”. The present results, indicating the low water consumption and high economic value of vegetables, followed by vineyards, is one of the factors that has to be taken into account in order to achieve an efficient allocation of water and economic resources.

7. Finally, a first estimation of trade in agricultural products is provided considering the international import-exports at a provincial level. The different sections of the Guadiana basin have different trade strategies. On the one hand, the Upper Guadiana basin is a net exporter, mainly of wine, barely importing any food commodity. On the other, the Lower Guadiana and TOP domain import low-value, high water-consuming cereals, while exporting high-value, low virtual-water content crops such as fruits. This reduces the demand on local (green and blue) water resources that can be used to provide ecological services and other more profitable uses.

Symbols

Symbol	Unit	Description
$CWR_{[c]}$	m^3/year	Crop water requirement of crop c
$CWC_{[c]}$	m^3/ha/year	Crop water consumption to produce a particular crop c, also called evapotranspirative demand
ET_0	mm/day	Reference evapotranspiration
ETc	mm/day	Crop evapotranspiration of a crop c
GVA	million €	Gross Value Added
Kc		Crop coefficient
V	m^3/ton	Virtual Water Content
V_b	m^3/ton	Blue Virtual Water Content
V_g	m^3/ton	Green Virtual Water Content
WF	m^3/year	Water Footprint
WF_b	m^3/year	Blue Water Footprint
WF_g	m^3/year	Green Water Footprint
WF_i	m^3/year	Internal Water Footprint

Glossary

Actual or crop evapotranspiration (ETc) –*Evapotranspiración real o del cultivo*– represents the actual rate of water uptake by the plant which is determined by the level of available water in the soil. It is an average value. Evapotranspiration comprises the simultaneous movement of water from the soil and vegetation into atmosphere through evaporation (E) and transpiration (T) (mm/time unit) (FAO, 2008).

Average precipitation –*Precipitación media*– double average over space and time of water falling on a country or region, referring to a given reference period (mm/time unit) (FAO, 2008).

Blue water –*Agua azul*– surface and ground water (Chapagain and Hoekstra, 2004).

Blue water evapotranspiration (ET_b) –*Evapotranspiración de agua azul*– is the field-evapotranspiration of irrigation water and is equal to the minimum of irrigation requirement (*IR*, mm/day) or effective irrigation (I_{eff}, mm/day) (mm/time period) (Hoekstra and Chapagain, 2008).

Blue virtual-water content (V_b) –*Contenido de agua virtual azul*– of a product is the volume of surface or ground water 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 evaporation of irrigation water from the field. In the cases of industrial production and domestic water supply, the blue water content of the product or service is equal to the part of the water withdrawn from ground or surface water that evaporates and thus does not return to the system where it came from or is directly out of the system, for instance from the coastal areas to the sea (m^3/ton) (Chapagain and Hoekstra, 2004).

Blue water footprint (WF_b) –*Huella hidrológica azul*– is the volume of freshwater that evaporated from the global blue water resources (surface and ground water) to produce the goods and services consumed by the individual or community (km^3/year, m^3/capita/year (Chapagain and Hoekstra, 2004).

Crop coefficient (kc) –*Coeficiente del cultivo*– is the ratio of the actual or crop evapotranspiration (ET_c) to the reference crop evapotranspiration (ET_o). It represents an integration of the effects of four primary characteristics (crop height, reflectance of the crop-soil surface, canopy resistance and evaporation from soil) that distinguish the crop from reference grass (Allen *et al.*, 1998).

Crop consumptive water use (CWU) –*Uso consuntivo agua del cultivo*– is defined as the accumulation of daily evapotranspiration over de complete growing period. It has two components: Green crop water and blue crop consumptive water use (m^3/ha) (Hoekstra and Chapagain, 2008).

Crop economic value –*Valor económico de la cosecha*– is defined as the economic value or price of origin received by the farmer for each commodity sold in the market (€/ton).

Crop water requirements (CWR) *–Necesidades hídricas del cultivo–* is defined as the total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate regime, when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield (mm/time period) (Allen *et al.*, 1998).

Crop water supply *–Agua aplicada al cultivo–* is the quantity of irrigation water, in addition to rainfall, applied to meet a crop's evapotranspiration need and normal crop production. It includes soil evaporation and some unavoidable losses under the given conditions. It is expressed in cubic meters for a crop period (m^3/year).

Crop yield (Y) *–Rendimiento del cultiv*o– represents the harvested production per unit of harvested area for crop products. Yield data can be obtained by dividing production data by harvested area (ton/ha) (FAO, 2008).

Cropping pattern *–Plan de cultivo–* sequence of different crops grown in regular order on any particular field or fields (FAO, 2008).

Cultivated land *–Superficie cultivable–* sum of arable land and land under permanent crops (FAO, 2008).

Economic water productivity *–Productividad económica del agua–* is the value of goods and services per cubic meter of water used, valued at the market price (€/m^3) (Llamas *et al*., 2001).

Effective irrigation (I_{eff}) *–Riego efectivo–* refers to the portion of total irrigation which is available for crop production (Chapagain and Hoekstra, 2004). That is, the irrigation dose excluding irrigation losses (mm/time period). In practice, however, irrigation losses have not been included since these data are generally not available per crop. According to Hoekstra and Chapagain (2008), in practice, this concept seems to be the same as irrigation requirement.

Effective rainfall (P_{eff}) *–Precipitación efectiva–* in irrigation practice, that portion of the total precipitation which is retained by the soil so that it is available for crop production (mm/time period) (FAO, 2008).

Effective rainfall in hydrology *–Precipitación efectiva en hidrología–* usually the term effective rainfall in hydrology means the quantity of water that is not evapotranspired and becomes blue water.

External water footprint (WF_e) *–Huella hidrológica externa–* is defined as the annual volume of water resources used in other countries or regions to produce goods and services consumed by the inhabitants of the country or region concerned (km^3/year, m^3/capita/year) (Chapagain and Hoekstra, 2004).

Green virtual-water content (V_g) *–Contenido de agua virtual verde–* of a product is the volume of rainwater that evaporated during the production process. This is mainly relevant for agricultural products, where it refers to the total rainwater evaporation from the field during the growing period of the crop (including both transpiration by the plants and other forms of evaporation) (m^3/ton) (Chapagain and Hoekstra, 2004).

Green water –*Agua verde*– rainwater stored in the soil as soil moisture, also called soil water (Chapagain and Hoekstra, 2004).

Green water evapotranspiration (ET_g) –*Evapotranspiración de agua verde*– is the evapotranspiration of rainfall and is equal to the minimum of crop water requirements (CWR, mm/day) or effective rainfall (P_{eff}, mm/day) (mm/ time period) (Hoekstra and Chapagain, 2008).

Green water footprint (WF_g) –*Huella hidrológica verde*– is the volume of water evaporated from green water resources in a particular region (km^3/year, m^3/capita/year) (Chapagain and Hoekstra, 2004).

Gross value added (GVA) –*Valor agregado bruto o valor añadido bruto*– is the value of goods and services produced in an economy at different stages of the productive process (million €). The gross value added is equal to net output or benefit that can be used for the remuneration of productive factors.

Internal water footprint (WF_i) –*Huella hidrológica interna*– is defined as the use of domestic water resources to produce goods and services consumed by inhabitants of a country or region (km^3/year, m^3/capita/year) (Chapagain and Hoekstra, 2004).

Irrigation dose –*Dosis de riego*– water artificially applied to soil and confined in time and space (FAO, 2008). It enables to meet the water requirements of a crop at a given time of its vegetative cycle or to bring the soil to the desired moisture level outside the vegetative cycle (ibid.). The irrigation of a field includes one or more watering per season (mm) (ibid.).

Irrigation efficiency –*Eficiencia de riego*– The ratio or percentage of the irrigation water consumed by crops of an irrigated farm, field or project to the water diverted from the source of supply. That is, the percentage of water delivered to the farm, field or project that is consumed by the crop, satisfying crop water requirements. Water application efficiency gives a general sense of how well an irrigation system performs its primary task of getting water to the plant roots. It is called farm irrigation efficiency or farm delivery efficiency when measured at the farm head-gate; field irrigation efficiency when measured at the field or plot; and water conveyance and delivery efficiency, or overall efficiency when measured at the source of supply (FAO, 2008).

Irrigation requirements (IR) –*Necesidad de riego*– is the quantity of irrigation water, in addition to rainfall, that must be applied to meet a crop's evapotranspiration need and normal crop production. It includes soil evaporation and some unavoidable losses under the given conditions. It is usually expressed in water-depth units (millimetres) and may be stated in monthly, seasonal or annual terms, or for a crop period (mm/time period) (FAO, 2008).

Land area irrigated by groundwater –*Superficie regada con aguas subterráneas (pozos)*– part of full or partial control area irrigated from wells (shallow wells and deep tubewells) or springs (ha, %) (FAO, 2008).

Land area irrigated by surface water –*Superficie regada con aguas superficiales*– part of the full or partial control area irrigated from rivers or lakes (reservoirs, pumping or diversion) (ha, %) (FAO, 2008).

Opportunity costs –*Coste de Oportunidad*– the cost of a resource, measured by the value of the next-best, alternative use of that resource (Stiglitz, 1997). The concept of opportunity cost is widely used in economics in identifying the most efficient use of scarce resources (Markandya *et al*., 2002).

Rainfed farming –*Agricultura de secano*– land cultivated benefiting from natural rainfall with no artificial addition of water (no irrigation) (FAO, 2008).

Reference crop evapotranspiration (ETo) –*Evapotranspiración de referencia*– is the evapotranspiration rate from a reference surface, not short in water. The reference is a hypothetical surface with extensive green grass cover with specific characteristics. *ETo* expresses the evaporating power of the atmosphere at a specific location and time of year and does not consider crop characteristics and soil factors (mm/time period) (Hoekstra and Chapagain, 2008).

River basin –*Cuenca hidrográfica*– means the area of land from which all surface run-off flows through a sequence of streams, rivers and, possibly, lakes into the sea at a single river mouth, estuary or delta (WFD, 2000).

River basin authority –*Confederación Hidrográfica u Organismo de cuenca*– along the lines of the 1985 Water Law, it is the public law institution in charge of surface and ground water management in one or more intercommunitarian river basins (Llamas *et al*., 2001).

Total economic agricultural production –*Producción económica agrícola total*– is defined as the total economic value received by the agricultural sector of the region for the commodities sold in the market without taking subsidies into account (total €).

Total economic agricultural productivity –*Productividad económica agrícola total*– is the total economic agricultural production per hectare (total €/ha).

Virtual-water content (V) –*Contenido de agua virtual*– 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). It refers to the sum of the water use in the various steps of the production chain. The virtual-water content of a product can also be defined as the volume of water that would have been required to produce the product at the place where the product is consumed (consumption-site definition). If not mentioned otherwise, we use the production-site definition. The adjective 'virtual' refers to the fact that most of the water used to produce a product is not contained in the product. The real-water content of products is generally negligible if compared to the virtual-water content (m^3/ton) (Chapagain and Hoekstra, 2004).

Virtual-water export (V_e) *–Exportación de agua virtual–* the virtual-water export of a country or region is the volume of virtual water associated with the export of goods or services from the country or region. It is the total volume of water required to produce the products for export (m^3/year) (Chapagain and Hoekstra, 2004).

Virtual-water flow *–Flujo de agua virtual–* the virtual-water flow between two nations or regions is the volume of virtual water that is being transferred from one place to another as a result of product trade (m^3/year) (Chapagain and Hoekstra, 2004).

Virtual-water import (V_i) *–Importación de agua virtual–* the virtual-water import of a country or region is the volume of virtual water associated with the import of goods or services into the country or region. It is the total volume of water used (in the export countries or regions) to produce the products. Viewed from the perspective of the importing country or region, this water can be seen as an additional source of water that comes on top of the domestically available water resources (m^3/year) (Chapagain and Hoekstra, 2004).

Virtual-water re-export ($V_{r,e}$) *–Re-exportación de agua virtual–* is the volume of virtual water associated with the export of goods or services to other countries or regions as a result of re-export of previously imported products (m^3/year) (Chapagain and Hoekstra, 2004).

Water consumption (final) *–Consumo final de agua (uso consuntivo)–* (consumptive water use) water abstracted which does not return to the hydrological system and is no longer available for use because it has evaporated, transpired, been incorporated into products and crops, consumed by man or livestock, been severely polluted, ejected directly to the sea or into evaporation areas (blind watershed) or otherwise removed from freshwater resources. Water losses during the transport of water between the point or points of abstraction and the point or points of use are excluded (m^3/year) (EEA, 2007; FAO, 2008; Llamas *et al*., 2001).

Water demand *–Demanda de agua–* water demand is defined as the volume of water requested by users to satisfy their needs. In a simplified way it is often considered equal to water abstraction, although conceptually the two terms do not have the same meaning (EEA, 2007; Llamas *et al.*, 2001).

Water footprint (WF) *–Huella hidrológica–* the water footprint of an individual or community is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community. A water footprint can be calculated for any well-defined group of consumers, including a family, business, village, city, province, state or nation. A water footprint is generally expressed in terms of the volume of water use per year (km^3/year, m^3/capita/year) (Chapagain and Hoekstra, 2004).

Water productivity *–Productividad del agua–* water productivity is an efficiency term quantified as a ratio of product output (goods and services) over water input. The output could be biological goods or products such as crop (grain fodder) or livestock (meat, egg, fish) and can be expressed in term of yields, nutritional value or economic return. The output could also be an environment service or function. Water productivity can be at different scales and for a mixture of goods and services (FAO, 2008).

Water supply *–Abastecimiento de agua–* water supply refers to the share of water abstraction which is supplied to users (excluding losses in storage, conveyance and distribution) (EEA, 2007).

Water use *–Uso del agua–* the different kinds of water use (agricultural, domestic, industrial), according to their purpose (Llamas *et al*., 2001).

Water use by agriculture *–Uso de agua en la agricultura–* annual quantity of water used for agricultural purposes including irrigation and livestock watering (billion m^3/year) (FAO, 2008).

Water use by agriculture for irrigation *–Uso del agua para riego–* (Irrigation use) artificial application of water on lands to assist in the growing of crops (and pastures). Can be done by spraying water under pressure on the land concerned ("spray irrigation"), by spreading water onto the land concerned ("flood irrigation"), by bringing it directly to the plant ("localised irrigation or drip irrigation") (m^3/year) (FAO, 2008).

Water use by the domestic sector *–Uso del agua para abastecimiento doméstico o urbano–* quantity of water use for domestic (urban) purposes. It is usually computed as the total amount of water supplied by public distribution networks, and usually includes the withdrawal by those industries connected to public networks (m^3/year) (FAO, 2008).

Water use by the industrial sector *–Uso del agua industrial–* annual quantity of water use by self-supplied industries not connected to any distribution network (m^3/year) (FAO, 2008).

Water use (irrigation) efficiency *–Eficiencia en el uso del agua–* ratio between the irrigation water absorbed by plants and the amount of water actually withdrawn from its source for the purpose of irrigation (UN, 2007).

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Appendixes

Appendix 1. Mancha and Don Benito agricultural region analysis

Appendix 1.1. General values

A. Agricultural general values in Mancha and Don Benito agricultural regions in 2001. Total rainfall of 424 mm in Ciudad Real and 491 mm in Badajoz – average year.

Agricultural region	Population[1]	Total area (km^2)	Crop area (ha)[1]			Irrigated area by irrigation system (ha)[2]				Average global irrigation efficiency[3*]
			Total	Rainfed	Irrigated	Sprinkler	Localized	Surface flood	Total	%
Mancha	208,012	4,676	390,177	240,931	149,246	65320 (47%)	69828 (51%)	2467 (2%)	137615 (100%)	0.8
Don Benito	89,605	1,957	123,987	53,194	70,793	12097 (22%)	12785 (23%)	29706 (54%)	54588 (100%)	0.64

1 *Source*: CHG (2008b) for the year 2001.
2 *Source*: CHG (2008b) from data from 1999 Agricultural Census (National Statistics Institute, INE) and 1T sheets (Spanish Ministry of Agriculture, Fisheries and Food, MAPA) for the years 1989 and 1999. This may explain the difference between irrigated crop area (for 2001) and the total irrigated area (for 1989 and 1999). In any case, we should try to clarify this difference.
3 Average global irrigation efficiency*, as used here, depends on the type of irrigation technique used by the farmer. Localized or drip irrigation is the most efficient system with a 0.9 coefficient, followed by sprinkler irrigation with 0.7 and finally, surface flood irrigation (riego por gravedad o “a manta”) with 0.5. From these efficiencies, an average irrigation efficiency* is given at provincial level by the CHG (2008b).

B. Agricultural general values in Mancha and Don Benito agricultural regions in 2001

Agricultural region	Total water ($10^6 m^3$/year)		Water origin[3] (%)		GVA[4]*		Employment[5]	
	Supply[1]	Total CWU_b[2]	Surface	Ground	Total 10^6€	€/ha	Post number	Post/ha
Mancha	450	360	0.04	0.96	259	663	10,373	0.03
Don Benito	380	243	0.94	0.06	89	719	4,945	0.04

1 Total crop water supply*. Source: CHG (2008b)
2 Total blue crop consumptive water use*. Source: CHG (2008b) (Thornthwaite method)
3 Surface and groundwater in volume percentage data, average value by agricultural region according to CHG (2008b).
4 Gross Value Added* is obtained by deducting intermediate consumption from final economic agricultural production. Thus gross value added is equal to net benefit for the farmer. Source: CHG (2008b)
5 Agricultural employment without including livestock or fisheries, total and per hectare. Source: CHG (2008b)

Appendix 1.2. Mancha agricultural region year 2001 Rainfall 424 mm (Ciudad Real) -average

A. Agricultural data (considering main crops representing 70% of the total crop area)

MANCHA	1. Area (ha)			2. Yield (ton/ha) [3]*		3. Production (10^3 ton/year)[4]		
Crop	Rainfed	Irrigated[5]	Total	Rainfed	Irrigated	Rainfed	Irrigated	Total
Vineyard	75563[1]	75935[1]	151499[1]	4.0	12.1	303	915	1218
Olive tree	23318[1]	3733[1]	27050[1]	1.7	2.4	41	9	49
Cereals:	51975[1]	48643[1]	100618[1]					
Oat	8370[2]	1581[2]	9951[2]	1.1	3.5	9	5	14
Wheat	9996[2]	10279[2]	20275[2]	1.0	3.4	10	34	45
Barley	24213[2]	29990[2]	54203[2]	1.0	3.6	25	107	132
Maize	9[2]	1853[2]	1862[2]	7.1	11.7	0	22	22
Tomato	0[2]	238[2]	238[2]		46.6	0	11	11
Total	141469	123609	265078					

1 Source: CHG (2008b)
2 Source: 1T sheets (MAPA, 2001b)
3 Source: "Agro-alimentary Statistics Yearbook" MAPA (2002) average value for the whole Ciudad Real province. It is noteworthy the small difference between irrigated and rainfed olive tree yield.
4 Calculated multiplying area (CHG, 2008b) and yield* (MAPA, 2002)
5 We have covered most of the irrigated crops, considering most part of irrigated surface.

B. Hydrologic data (considering main crops representing 70% of the total crop area)

MANCHA	4. Crop Consumptive Water Use* (CWU) (m^3/ha)				5. Virtual Water Content* (V) (m^3/ton)			
	Rainfed	Irrigated			Rainfed	Irrigated		
Crop	CWU_g[1*]	CWU_g[1*]	CWU_b[2*]	Total	V_g[3*]	V_g[4*]	V_b[5*]	Total[6]
Vineyard	1118	1118	4437	5555	279	93	368	461
Olive tree	1458	1458	4151	5609	839	619	1763	2382
Cereals:								
Oat	1540	1540	2200	3739	1446	446	638	1084
Wheat	1717	1717	3933	5650	1651	513	1174	1687
Barley	1540	1540	2200	3739	1495	430	614	1044
Maize	0	392	6534	6926	0	34	558	592
Tomato	0	320	7013	7333	0	7	150	157

1 CWU_g Green crop consumptive water use* estimated using the CROPWAT model (FAO, 2003) (see methodology section).
2 CWU_b Blue crop consumptive water use* estimated using the CROPWAT model (FAO, 2003) (see methodology section). These numbers are slightly different from the ones from the CHG (2005) (Table 16).
3 V_g Green virtual water content* calculated dividing CWU_g* (Table 4.4) by rainfed yield* (Table 3.2)
4 V_g Green virtual water content* calculated dividing CWU_g* (Table 4.4) by irrigated yield* (Table 3.2)
5 V_b Blue virtual water content* calculated dividing CWU_b* (Table 4.4) by irrigated yield* (Table 3.2)
6 Calculated dividing total irrigated CWU* (Table 4.4) by irrigated yield* (Table 3.2)

C. Hydrologic data (considering main crops representing 70% of the total crop area)

MANCHA	5. Total Crop Consumptive Water Use (CWU) ($10^6 m^3$/year)					6. Total Crop Water Supply[6]* ($10^6 m^3$/year)		
	Rainfed	Irrigated				Irrigated		
	Green water[1*]	Green water[2*]	Blue water[3*]			Blue water		
Crop			Total	Surf.[4]	Gr.[5]	Total	Surface	Ground
Vineyard	84	85	337	13	324	421	16	405
Olive tree	34	5	15	1	15	19	1	19
Cereals:								
Oat	13	2	3	0	3	4	0	4
Wheat	17	18	40	2	39	51	2	49
Barley	37	46	66	2	63	82	3	79
Maize	0	1	12	0	12	15	1	15
Tomato	0	0	2	0	2	2	0	2
Total	186	157	476	18	458	595[7]	22	573

1 Total green crop consumptive water use is calculated multiplying CWU_g* (Table 4.4) by rainfed area (Table 3.1)
2 Total green crop consumptive water use calculated multiplying CWU_g* (Table 4.4) by irrigated area (Table 3.1)
3 Total blue crop consumptive water use calculated multiplying CWU_b* (Table 4.4) by irrigated area (Table 3.1)
4 Total blue crop consumptive water use coming from surface water calculated multiplying total blue crop consumptive water use (Table 5.5) by surface water percentage (Table 2)
5 Total blue crop consumptive water use coming from groundwater calculated multiplying total blue crop consumptive water use (Table 5.5) by groundwater percentage (Table 2)
6 Calculated dividing total, surface or groundwater blue crop consumptive water use (Table 5.5) by irrigation average efficiency (CHG, 2008b) in the province, which is 0.8 according to Table 1.
7 According to the PEAG total water consumption varies from 450 and 525 Mm^3/year in the Upper Guadiana. Along with the same source, irrigation water withdrawals are to be reduced to 310 Mm^3/year in this region (CHG, 2008c).

D. Economic data (considering main crops representing 70% of the total crop area)

MANCHA	7. Economic data						8. Water economic productivity*	
	Value[1]	Agricultural economic productivity[2]		Total economic agricultural production[3]			Irrigated (€/m^3)	
		Rainfed	Irrigated	Rainfed	Irrigated	Total	CWU_b[4]	Supply[5]
Crop	€/ton	10^3 €/ha	10^3 €/ha	10^3€	10^3€	10^3€	Total	Total
Vineyard	455	1,8	5,5	137775	416052	553827	1,2	1,0
Olive tree	498	0,9	1,2	20166	4374	24539	0,3	0,2
Cereals:								
Oat	125	0.1	0.4	1112	680	1792	0.2	0.2
Wheat	149	0.2	0.5	1547	5124	6671	0.1	0.1
Barley	127	0.1	0.5	3155	13582	16736	0.2	0.2
Maize	136	1.0	1.6	9	2958	2967	0.2	0.2
Tomato	336	-	15.7	0	3727	3727	2.2	1.8
Total				163763	446497	610260	0.5	0.4

1 Average value for the whole Spain. "Agro-alimentary Statistics Yearbook" MAPA (2002).
2 Calculated by dividing total € (Table 6.7) by hectare of each crop (Table 3.1)
3 Calculated by multiplying €/ton (Table 6.7) by tones (Table 3.3). Obviously, the total agricultural production value given here (262 10^6 €) is higher than the GVA* (259 10^6 €)
4 Calculated by dividing economic value (€/ton) (Table 6.7) by blue virtual water content* (V_b) (m^3/ton) (Table 4.5)
5 Calculated by dividing irrigated total € (Table 6.7) by blue crop water supply* (m^3/year) (Table 5.6)

Appendix 1.3. Don Benito agricultural region year 2001 Rainfall 491 mm (Badajoz) - average Considering the 50% of the total crop area.

A. Agricultural data (considering main crops representing 50% of the total crop area)

DON BENITO	1. Area (ha)			2. Yield (ton/ha)*[3]		3. Production (10^3 ton/year)[4]		
Crop	Rainfed	Irrigated	Total	Rainfed	Irrigated	Rainfed	Irrigated	Total
Vineyard	1151[1]	291[1]	1442[1]	5.1	8.0	6	2	8
Olive tree	10871[1]	9133[1]	20004[1]	1.5	5.0	17	46	62
Cereals:	24601[1]	42976[1]	67576[1]					
Oat	4234[2]	451[2]	4685[2]	1.7	3.0	7	1	9
Wheat	12562[2]	2505[2]	15067[2]	3.2	4.2	40	11	51
Barley	7340[2]	939[2]	8279[2]	3.1	4.0	23	4	27
Maize	0[2]	12830[2]	12830[2]	-	12.0	0	154	154
Tomato	50[2]	6321[2]	6371[2]	-	57.1	0	361	361
Total	36208	32470	68678					

1 Source: CHG (2008b)
2 Source: 1T sheets (MAPA, 1999) for the year 1999.
3 Source: "Agro-alimentary Statistics Yearbook" MAPA (2002) average value for the whole Badajoz province
4 Calculated multiplying area (CHG, 2008b) and yield* (MAPA, 2002)

B. Hydrologic data (considering main crops representing 50% of the total crop area)

DON BENITO	4. Crop Consumptive Water Use* (CWU) (m^3/ha)				5. Virtual Water Content* (V) (m^3/ton)			
	Rainfed	Irrigated			Rainfed	Irrigated		
	CWU_g[1]	CWU_g[1]	CWU_b[2]	Total				
Crop					V_g[3]	V_g[4]	V_b[5]	Total[6]
Vineyard	1017	1017	4650	5668	201	127	581	708
Olive tree	1179	1179	4572	5751	769	236	914	1150
Cereals:								
Oat	1429	1429	2415	3844	841	476	805	1281
Wheat	1530	1530	4268	5797	478	364	1015	1379
Barley	1429	1429	2415	3844	461	357	604	961
Maize	-	366	6712	7078	-	30	559	590
Tomato	-	326	7179	7505	-	6	126	131

1 CWU_g Green crop consumptive water use* estimated using the CROPWAT model (FAO, 2003) (see methodology section).
2 CWU_b Blue crop consumptive water use* estimated using the CROPWAT model (FAO, 2003) (see methodology section). These numbers are slightly different from the ones from the CHG (2005) (Table 16).
3 V_g Green virtual water content* calculated dividing CWU_g* (Table 8.4) by rainfed yield* (Table 7.2)
4 V_g Green virtual water content* calculated dividing CWU_g* (Table 8.4) by irrigated yield* (Table 7.2)
5 V_b Blue virtual water content* calculated dividing CWU_b* (Table 8.4) by irrigated yield* (Table 7.2)
6 Calculated dividing total irrigated* *CWU** (Table 8.4) by irrigated yield* (Table 7.2)

C. Hydrologic data (considering main crops representing 50% of the total crop area)

DON BENITO	5. Total Crop Consumptive Water Use ($10^6 m^3$/year)					6. Total Crop Water Supply[6] ($10^6 m^3$/year)		
	Rainfed	Irrigated				Irrigated		
	Green water[1]	Green water[2]	Blue water[3]			Blue water		
Crop			Total	Surf.[4]	Gr.[5]	Total	Surface	Ground
Vineyard	1	0	1	1	0	2	2	0
Olive tree	13	11	42	39	2	65	61	4
Cereals:								
Oat	6	1	1	1	0	2	2	0
Wheat	19	4	11	10	1	17	16	1
Barley	10	1	2	2	0	4	3	0
Maize	0	5	86	81	5	135	127	8
Tomato	0	2	45	43	3	71	67	4
Total	50	24	189	178	11	295	278	16

1 Total green crop consumptive water use is calculated multiplying CWU_g* (Table 8.4) by rainfed area (Table 7.1)
2 Total green crop consumptive water use calculated multiplying CWU_g* (Table 8.4) by irrigated area (Table 7.1)
3 Total blue crop consumptive water use calculated multiplying CWU_b* (Table 8.4) by irrigated area (Table 7.1)
4 Total blue crop consumptive water use coming from surface water calculated multiplying total blue crop consumptive water use (Table 9.5) by surface water percentage (Table 2)
5 Total blue crop consumptive water use coming from groundwater calculated multiplying total blue crop consumptive water use (Table 9.5) by groundwater percentage (Table 2)
6 Calculated dividing total, surface or groundwater blue crop consumptive water use (Table 9.5) by irrigation average efficiency in the province which is 0.64 according to Table 1.

D. Economic data (considering main crops representing 50% of the total crop area)

DON BENITO	7. Economic data						8. Water economic productivity*	
	Value[1]	Agricultural economic productivity[2]		Total economic agricultural production[3]			Irrigated (€/m^3)	
		Rainfed	Irrigated	Rainfed	Irrigated	Total	CWU_b[4]	Supply[5]
Crop	€/ton	10^3 €/ha	10^3 €/ha	10^3€	10^3€	10^3€	Total	Total
Vineyard	455	2,3	3,6	2650	1059	3709	0,8	0,5
Olive tree	498	0,8	2,5	8292	22723	31015	0,5	0,3
Cereals:								
Oat	125	0.2	0.4	898	169	1066	0.2	0.1
Wheat	149	0.5	0.6	5987	1567	7554	0.1	0.1
Barley	127	0.4	0.5	2878	475	3354	0.2	0.1
Maize	136	-	1.6	-	21000	21000	0.2	0.2
Tomato	336	-	19	-	121251	121251	2.7	1.7
Total				20706	168243	188949	0.6	0.4

1 Average value for the whole Spain. "Agro-alimentary Statistics Yearbook" MAPA (2002).
2 Calculated by dividing total € (Table 10.7) by hectare (Table 7.1)
3 Calculated by multiplying €/ton (Table 10.7) by tones (Table 7.3). Obviously, the total agricultural production value given here (178 10^6 €) is higher than the GVA* (89 10^6 €)
4 Calculated by dividing economic value (€/ton) (Table 10.7) by blue virtual water content* (V_b) (m^3/ton) (Table 8.5)
5 Calculated by dividing irrigated total € (Table 10.7) by blue crop water supply (m^3/year) (Table 9.6)

Appendix 2. Guadiana river basin analysis

A. Crop Area, Production and Yield (2001)

B) UPPER GUADIANA[1]	Area (ha)[2]			Production (ton/year)[3]			Yield (kg/ha)[4]	
Crops	Rainfed	Irrigated	Total	Rainfed	Irrigated	Total	Rainfed	Irrigated
Grain cereals[5]:	478.572	97.634	576.206	1.959.752	740.309	2.700.061	4095	7583
Cereal - Wheat, barley, oat							1045	3460
Cereal – Maize							7145	11705
Grain legumes – Veza, yeros	68.974	10.567	79.541	17.864	11.835	29.699	259	1120
Potatoes	411	733	1.143	4.986	17.855	22.842	12140	24369
Industrial crops – Sunflower	73.038	10.450	83.488	24.541	16.752	41.293	336	1603
Fodder – Veza, alfalfa	30.312	7.701	38.013	182.784	173.269	356.052	6030	22500
Vegetables – melon	488	13.337	13.826	3.959	369.447	373.406	8110	27700
Flowers and ornamental plants	133	100	234					
Seeds and small plants	0	21	21					
Other grass crops	59	1.895	1.954					
Fallow land	343.142	0	343.142					
Vegetable gardens	0	39	39					
Citrus	0	10	10				-	-
Temperate climate fruit trees	84	210	295					
Subtropical climate fruit trees	0	0	0					
Dry fruit trees	5.503	293	5.796					
Olive tree – for olive oil	134.687	13.213	147.900	234.086	31.116	265.202	1738	2355
Vineyard – for wine production	199.277	131.866	331.143	799.100	1.588.985	2.388.085	4010	12050
Nursery	0	25	25					
Other permanent crops	185	6	191					
Greenhouse tree crops	0	2	2					
Mushrooms		15	15					
Greenhouses		86	86					
Total	1.334.865	288.205	1.623.070	3.227.072	2.949.568	6.176.640	4590	12410
	Surface[6]	26.390						
	groundwater[7]	237.857						

1 The Upper Guadiana includes a fraction of Castilla-La Mancha Autonomous region.
2 Source: CHG (2008b)
3 Calculated multiplying area (CHG, 2008b) and yield (MAPA, 2002)
4 Source: MAPA (2007)
5 Grain cereals comprise main cereals in the area according to MAPA 1T sheets.
6 Irrigated area with surface water
7 Irrigated area with groundwater

C) MIDDLE GUADIANA[1]	Area (ha)[2]			Production (ton/year)[3]			Yield (kg/ha)[4]	
Crops	Rainfed	Irrigated	Total	Rainfed	Irrigated	Total	Rainfed	Irrigated
Grain cereals[5]:	281.182	96.161	377.343	750.101	742.533	1.492.634	2668	7722
Cereal - Wheat, barley, oat							2668	3734
Cereal – Maize							-	12000
Cereal – Rice							-	7431
Grain legumes – Chick peas	19.535	1.532	21.067	14.651		14.651	750	-
Potatoes	6	430	436	-	10.758	10.758	-	25000
Industrial crops - Sunflower	16.372	15.541	31.913	14.964	44.510	59.474	914	2864
Fodder – Clover, veza	46.957	2.558	49.514	469.565	0	469.565	10000	-
Vegetables – Tomato	504	21.597	22.101	0	1.232.619	1.232.619	-	57073
Flowers and ornamental plants	6	62	68					
Seeds and small plants	0	77	77					
Other grass crops	2	1.859	1.861					
Fallow land	143.481	0	143.481					
Vegetable gardens	0	88	88					
Citrus	0	41	41	0	489	489	-	12000
Temperate climate fruit trees	5.060	7.807	12.867					
Subtropical climate fruit trees	0	3	3					
Dry fruit trees	1.716	1.005	2.721					
Olive tree for olive oil and table	190.661	47.778	238.439	328.700	238.891	567.591	1724	5000
Vineyard for wine production	59.116	11.704	70.819	299.362	93.630	392.992	5064	8000
Nursery	0	69	69					
Other permanent crops	67	0	67					
Greenhouse tree crops	0	4	4					
Mushrooms		0	0					
Greenhouses		77	77					
Total	764.664	208.393	973.057	1.877.343	2.363.430	4.240.774	2950	14082
	Surface[6]	121.291						
	groundwater[7]	23.061						

1 The Middle Guadiana includes a fraction of Extremadura (Badajoz and Cáceres).
2 Source: CHG (2008b)
3 Calculated multiplying area (CHG, 2008b) and yield (MAPA, 2002)
4 Source: MAPA (2007)
5 Grain cereals comprise main cereals in the area according to MAPA 1T sheets.
6 Irrigated area with surface water
7 Irrigated area with groundwater

D) TOP[1]	Area (ha)[2]			Production (ton/year)[3]			Yield (kg/ha)[4]	
Crops	Rainfed	Irrigated	Total	Rainfed	Irrigated	Total	Rainfed	Irrigated
Grain cereals[5] – Wheat	23,771	1,221	24,992	58,002	4,188	62,190	2440	3430
Grain legumes – Lupin, veza	477	206	683	324	299	623	679	1450
Potatoes	41	121	162	353	1,667	2,020	8554	13807
Industrial crops – Sunflower	10,659	2,579	13,237	11,192	5,286	16,478	1050	2050
Fodder – Veza	809	234	1,043	12,948		12,948	16000	-
Vegetables – Strawberry	131	4,374	4,505	0	147,600	147,600	0	33741
Flowers and ornamental plants	0	66	66					
Seeds and small plants	0	1	1					
Other grass crops	0	0	0					
Fallow land	18,900	0	18,900					
Vegetable gardens	0	27	27					
Citrus	0	7,665	7,665		118,337	118,337	-	15,438
Temperate climate fruit trees	292	1,789	2,081					
Subtropical climate fruit trees	0	101	101					
Dry fruit trees	1,787	81	1,868					
Olive tree for olive oil and table	10,171	1,059	11,229	8,747	1,673	10,420	860	1,580
Vineyard for wine and grape	3,178	129	3,307	23,549	1,056	24,605	7,410	8,200
Nursery	0	6	6					
Other permanent crops	2	0	2					
Greenhouse tree crops	0	64	64					
Mushrooms		0	0					
Greenhouses		352	352					
Total	70,220	20,073	90,293	115,115	280,106	395,221	5285	9962
	Surface[6]	11,076						
	groundwater[7]	8,695						

1 In line with CHG (2008b), TOP region is the Tinto, Odiel and Piedras river basin complementary region.
2 Source: CHG (2008b)
3 Calculated multiplying area (CHG, 2008b) and yield (MAPA, 2002)
4 Source: MAPA (2007)
5 Grain cereals comprise main cereals in the area according to MAPA 1T sheets.
6 Irrigated area with surface water
7 Irrigated area with groundwater

D) LOWER GUADIANA[1]	Area (ha)[2]			Production (ton/year)[3]			Yield (kg/ha)[4]	
Crops	Rainfed	Irrigated	Total	Rainfed	Irrigated	Total	Rainfed	Irrigated
Grain cereals[5] – Wheat	7,363	203	7,566	17,965	696	18,661	2,440	3,430
Grain legumes – Lupin, veza	121	11	132	82	16	98	679	1,450
Potatoes	17	5	22	147	64	210	8,554	13,807
Industrial crops – Sunflower	340	127	468	358	261	618	1,050	2,050
Fodder – Veza	779	234	1,012	12,457		12,457	16,000	-
Vegetables – Strawberry	23	380	403	0	12,817	12,817	-	33,741
Flowers and ornamental plants	0	7	7					
Seeds and small plants	0	0	0					
Other grass crops	0	0	1					
Fallow land	10,839	0	10,839					
Vegetable gardens	0	20	20					
Citrus	0	1,672	1,672		25,817	25,817	-	15,438
Temperate climate fruit trees	104	360	464					
Subtropical climate fruit trees	0	1	1					
Dry fruit trees	3,433	24	3,456					
Olive tree for olive oil and table	5,324	246	5,570	4,579	388	4,967	860	1,580
Vineyard for wine and grape	63	251	314	465	2,061	2,526	7,410	8,200
Nursery	0	0	0					
Other permanent crops	0	0	0					
Greenhouse tree crops	0	0	0					
Mushrooms		0	0					
Greenhouses		7	7					
Total	28,406	3,548	31,954	36,053	42,119	78,171	5,285	9,962
	Surface6	2,435						
	groundwater 7	780						

1 The Lower Guadiana basin comprises the Guadiana basin part in Huelva.
2 Source: CHG (2008b)
3 Calculated multiplying area (CHG, 2008b) and yield (MAPA, 2002)
4 Source: MAPA (2007)
5 Grain cereals comprise main cereals in the area according to MAPA 1T sheets.
6 Irrigated area with surface water
7 Irrigated area with groundwater

B. Crop water consumption (m^3/ha), total water resource consumption (10^6 m^3/year) and virtual water content (m^3/ton) (2001).

	Crop Water Consumption (m^3/ha)					Total use of water resources ($10^6 m^3$/year)					Virtual Water Content (V) (m^3/ton)				
B) UPPER GUADIANA[1]	Rainfed	Irrigated				Rainfed	Irrigated				Rainfed	Irrigated			
Crop	V_g[2]	V_g[2]	V_b[3]	V_b[4]	Total	V_g[2]*A[5]	V_g[2]*A[5]	V_b[3]*A[5]	V_b[4]*A[5]	Total*A[5]	V_g[2]	V_g[2]	V_b[3]	V_b[4]	Total
Grain cereals[6]:	1238	1238	3303	2599	4541	593	121	322	254	443	302	163	436	343	599
Cereal - Wheat, barley, oat	1520	1520	2225		3746						1455	439	643		1083
Cereal - Maize	392	392	6534		6926						55	34	558		592
Grain legumes Veza, yeros	911	911	2598	2254	3510	63	10	27	24	37	3519	814	2320	2012	3133
Potatoes	370	370	6035	2864	6404			4	2	5	30	15	248	118	263
Industrial crops – Sunflower	311	311	5625	3168	5936	23	3	59	0	62	924	194	3509	0	3703
Fodder – Veza, alfalfa	816	816	4177	4079	4993	25	6	32	31	38	135	36	186	181	222
Vegetables – Melon	290	290	5136	3741	5426	0	4	69	50	72	36	10	185	135	196
Flowers, ornamental plants				4052					0						
Seeds and small plants				3400					0						
Other grass crops				3880					7						
Fallow land									0						
Vegetable gardens				3906					0						
Citrus				3900					0						
Temperate climate fruit trees				3980					1						
Subtropical climate fruit trees															
Dry fruit trees				4915					1						
Olive tree for olive oil	1057	1057	2502	1893	3560	142	14	33	25	47	608	449	1063	804	1512
Vineyard for wine production	854	854	2890	2692	3744	170	113	381	355	494	213	71	240	223	311
Nursery				3400											
Other permanent crops				4047											
Greenhouse tree crops				3400											
Mushrooms				18000											
Greenhouses[6]				4200											
Total	731	731	4033	2932	4764	1016	271	928	752	1199	728	223	939	477	1161

1 The Upper Guadiana includes a fraction of Castilla-La Mancha Autonomous region.
2 V_g: Green virtual water. Source: Own elaboration.
3 V_b: Blue virtual water. Source: Own elaboration.
4 V_b: Blue virtual water. Source: CHG (2008b)
5 A: Area in hectares
6 Grain cereals comprise main cereals in the area according to MAPA 1T sheets.

	Crop Water Consumption (m^3/ha)					Total use of water resources ($10^6 m^3$/year)					Virtual Water Content (V) (m^3/ton)				
C) MIDDLE GUADIANA[1]	Rainfed	Irrigated				Rainfed	Irrigated				Rainfed	Irrigated			
Crop	V_g^2	V_g^2	V_b^3	V_b^4	Total	$V_g^2 * A^5$	$V_g^2 * A^5$	$V_b^3 * A^5$	$V_b^4 * A^5$	$Total * A^5$	V_g^2	V_g^2	V_b^3	V_b^4	Total
Grain cereals[6]:	1378	1052	4462	4.095	5514	387	101	429	394	530	516	136	578	530	714
Cereal - Wheat, barley, oat	1378	1378	2473		3851						516	369	662		1031
Cereal - Maize	-	366	6712		7078							30	559		590
Cereal - Rice	-	760	8178		8938							102	1100		1203
Grain legumes – Chick peas	325	-	-	3.050		6	0	0	5	0	433				
Potatoes	-	970	3437	2.821	4406	0	0	1	1	2					
Industrial crops – Sunflower	325	325	5741		6065	5	5	89	0	94	355	113	2004	0	2118
Fodder – Clover, veza	1665	1665	1745	5.346		78			14	0	167				
Vegetables – Tomato	317	317	6592	4.043	6909	0	7	142	87	149	-	6	115	71	121
Flowers, ornamental plants				4.050					0						
Seeds and small plants				3.400					0						
Other grass crops				4.430					8						
Fallow land															
Vegetable gardens				3.637					0						
Citrus	-	2244	6000	3.900	8244		0	0	0			187	500	325	687
Temperate climate fruit trees				3.718					29						
Subtropical climate fruit trees				4.000					0						
Dry fruit trees				5.500					6						
Olive tree	1048	1048	3733	1.975	4781	200	50	178	94	228	608	210	747	395	956
Vineyard	912	912	3901	2.683	4814	54	11	46	31	56	180	114	488	335	602
Nursery				3.400											
Other permanent crops															
Greenhouse tree crops				3.400											
Mushrooms															
Greenhouses				4.200											
Total	853	1067	4451	3758	5819	731	174	886	671	1061	397	141	750	276	891

1 The Middle Guadiana includes a fraction of Extremadura (Badajoz and Cáceres).
2 V_g: Green virtual water. Source: Own elaboration.
3 V_b: Blue virtual water. Source: Own elaboration.
4 V_b: Blue virtual water. Source: CHG (2008b)
5 A: Area in hectares
6 Grain cereals comprise main cereals in the area according to MAPA 1T sheets.

	Crop Water Consumption (m^3/ha)					Total use of water resources ($10^6 m^3$/year)					Virtual Water Content (V) (m^3/ton)				
D) TOP[1]	Rainfed	Irrigated				Rainfed	Irrigated				Rainfed	Irrigated			
Crop	V_g[2]	V_g[2]	V_b[3]	V_b[4]	Total	V_g[2]*A[5]	V_g[2]*A[5]	V_b[3]*A[5]	V_b[4]*A[5]	Total*A[5]	V_g[2]	V_g[2]	V_b[3]	V_b[4]	Total
Grain cereals[6] – Wheat	1380	1380	2760	3677	4140	33	2	3	4	5	565	402	805	1072	1207
Grain legumes – Lupin, veza	752	752	4227	3050	4979	0	0	1	1	1	1108	519	2915	2103	3434
Potatoes	1015	1015	3560	1240	4575	0	0	0	0	1	119	74	258	90	331
Industrial crops – Sunflower	0	0	5936		5936	0	0	15	0	15	0	0	2896	0	2896
Fodder – Veza and others	1505	1505	3674	5023	5178	1			1		94				
Vegetables – Strawberry	1688	1688	2836	3840	4523	0	7	12	17	20	-	50	84	114	134
Flowers and ornamental plants				4050					0						
Seeds and small plants				3400					0						
Other grass crops				---											
Fallow land															
Vegetable gardens				3817					0						
Citrus	-	2828	5586	3952	8415		22	43	30	65		183	362	256	545
Temperate climate fruit trees				3765					7						
Subtropical climate fruit trees				4000					0						
Dry fruit trees				5900					0						
Olive tree for oil and table	589	589	1601	2282	2189	6	1	2	2	2	685	373	1013	1444	1386
Vineyard for wine and grape	564	564	1902	2888	2466	2	0	0	0	0	76	69	232	352	301
Nursery				3400					0						
Other permanent crops				---											
Greenhouse tree crops				3400					0						
Mushrooms				---											
Greenhouses[6]				4200					1						
Total	936	1147	3565	3635	4711	42	32	77	66	109	378	209	1071	679	1279

1 In line with CHG (2008b), TOP region is the Tinto, Odiel and Piedras river basin complementary region.
2 V_g: Green virtual water. Source: Own elaboration.
3 V_b: Blue virtual water. Source: Own elaboration.
4 V_b: Blue virtual water. Source: CHG (2008b)
5 A: Area in hectares
6 Grain cereals comprise main cereals in the area according to MAPA 1T sheets.

	Crop Water Consumption (m^3/ha)					Total use of water resources ($10^6 m^3$/year)					Virtual Water Content (V) (m^3/ton)				
D) LOWER GUADIANA[1]	Rainfed	Irrigated				Rainfed	Irrigated				Rainfed	Irrigated			
Crop	V_g[2]	V_g[2]	V_b[3]	V_b[4]	Total	V_g[2]*A[5]	V_g[2]*A[5]	V_b[3]*A[5]	V_b[4]*A[5]	Total*A[5]	V_g[2]	V_g[2]	V_b[3]	V_b[4]	Total
Grain cereals[6] – Wheat	1380	1380	2760	3677	4140	10	0	1	1	1	565	402	805	1072	1207
Grain legumes – Lupin, veza	752	752	4227	3050	4979	0	0	0	0	0	1108	519	2915	2103	3434
Potatoes	1015	1015	3560	1240	4575	0	0	0	0	0	119	74	258	90	331
Industrial crops – Sunflower	0	0	5936		5936	0	0	1	0	1	0	0	2896	0	2896
Fodder – Veza and others	1505	1505	3674	5023	5178	1			1		94				
Vegetables – Strawberry	1688	1688	2836	3840	4523	0			1	2	-	50	84	114	134
Flowers and ornamental plants				4050					0						
Seeds and small plants				3400					0						
Other grass crops				---											
Fallow land															
Vegetable gardens				3817					0						
Citrus	-	2828	5586	3952	8415	0	5	9	7	14		183	362	256	545
Temperate climate fruit trees				3765					1						
Subtropical climate fruit trees				4000					0						
Dry fruit trees				5900					0						
Olive tree for oil and table	589	589	1601	2282	2189	3	0	0	1	1	685	373	1013	1444	1386
Vineyard for wine and grape	564	564	1902	2888	2466	0	0	0	1	1	76	69	232	352	301
Nursery				3400					0						
Other permanent crops				---											
Greenhouse tree crops				3400					0						
Mushrooms				---											
Greenhouses[6]				4200					0						
Total	936	1147	3565	3635	4711	15	6	13	13	19	378	209	1071	679	1279

1 The Lower Guadiana basin comprises the Guadiana basin part in Huelva.
2 V_g: Green virtual water. Source: Own elaboration.
3 V_b: Blue virtual water. Source: Own elaboration.
4 V_b: Blue virtual water. Source: CHG (2008b)
5 A: Area in hectares
6 Grain cereals comprise main cereals in the area according to MAPA 1T sheets.

C. Economic value and economic water productivity (€/m^3) (2001)

	Economic value					Water economic productivity[5]	GVA[6]	Employment[7]
B) UPPER GUADIANA[1]	€/ha[2]	€/ha[2]	€/ton[3]	Total million €[4]		€/m^3	million €	post number
Crop	Rainfed	Irrigated		Rainfed	Irrigated	Irrigated		
Grain cereals[8]:	549	1017	134	263	99	0,3		
Cereal - Wheat, barley, oat			133					
Cereal - Maize			136					
Grain legumes – Veza, yeros	46	197	176	3	2	0,1		
Potatoes	2508	5035	207	1	4	0,8		
Industrial crops – Sunflower		410	256		4	0,1		
Fodder – Veza, alfalfa			101					
Vegetables – Melon	2092	7144	258	1	95	1,4		
Flowers, ornamental plants								
Seeds and small plants								
Other grass crops								
Fallow land								
Vegetable gardens								
Citrus			192					
Temperate climate fruit trees								
Subtropical climate fruit trees								
Dry fruit trees								
Olive tree for olive oil	865	1172	498	116	15	0,5		
Vineyard for wine production	1823	5479	455	363	722	1,9		
Nursery								
Other permanent crops								
Greenhouse tree crops								
Mushrooms								
Greenhouses								
Total	560	3271		748	943	1,0	599	26818

1 The Upper Guadiana includes a fraction of Castilla-La Mancha Autonomous region.
2 Total economic value (total €) divided by area (ha)
3 Source: MAPA (2002)
4 Economic value (€/ton) multiplied by production (ton/year). Source: MAPA (2002)
5 Total economic value (total €) divided by the total use of water resources (m3/year)
6 Gross Value Added (GVA). Source: CHG (2008b)
7 Source: CHG (2008b)
8 Grain cereals comprise main cereals in the area according to MAPA 1T sheets.

	Economic value					Water economic productivity[5]	GVA[6]	Employment[7]
C) MIDDLE GUADIANA1	€/ha[2]	€/ha[2]	€/ton[3]	Total million €[4]		€/m^3	million €	post number
Crop	Rainfed	Irrigated		Rainfed	Irrigated	Irrigated		
Grain cereals[8]:	435	1259	163	122	121	0,3		
Cereal - Wheat, barley, oat			133					
Cereal - Maize			136					
Cereal - Rice			279					
Grain legumes – Chick peas	613		817	12				
Potatoes		5165	207		2	1,5		
Industrial crops – Sunflower		732	256		11	0,1		
Fodder – Clover, veza	0		101					
Vegetables – Tomato	0	19182	336	0	414	2,9		
Flowers, ornamental plants								
Seeds and small plants								
Other grass crops								
Fallow land								
Vegetable gardens								
Citrus		2302	192		0	0,4		
Temperate climate fruit trees								
Subtropical climate fruit trees								
Dry fruit trees								
Olive tree for oil and table	858	2488	498	164	119	0,7		
Vineyard for wine production	2303	3638	455	136	43	0,9		
Nursery								
Other permanent crops								
Greenhouse tree crops								
Mushrooms								
Greenhouses								
Total	568	3409		434	711	0,8	413	22991

1 The Middle Guadiana includes a fraction of Extremadura (Badajoz and Cáceres).
2 Total economic value (total €) divided by area (ha)
3 Source: MAPA (2002)
4 Economic value (€/ton) multiplied by production (ton/year). Source: MAPA (2002)
5 Total economic value (total €) divided by the total use of water resources (m3/year)
6 Gross Value Added (GVA). Source: CHG (2008b)
7 Source: CHG (2008b)
8 Grain cereals comprise main cereals in the area according to MAPA 1T sheets.

	Economic value					Water economic productivity[5]	GVA[6]	Employment[7]
D) TOP[1]	€/ha[2]	€/ha[2]	€/ton[3]	Total million €[4]		€/m^3	million €	post number
Crop	Rainfed	Irrigated		Rainfed	Irrigated	Irrigated		
Grain cereals[8] – Wheat	325	457	133	8	1	0,2		
Grain legumes – Lupin, veza	129	276	190	0	0	0,1		
Potatoes	1767	2852	207	0	0	0,8		
Industrial crops – Sunflower		524	256		1	0,1		
Fodder – Veza and others			101					
Vegetables - Strawberries	0	28039	831	0	123	9,9		
Flowers and ornamental plants								
Seeds and small plants								
Other grass crops								
Fallow land								
Vegetable gardens								
Citrus		2961	192		23	0,5		
Temperate climate fruit trees								
Subtropical climate fruit trees								
Dry fruit trees								
Olive tree	428	786	498	4	1	0,5		
Vineyard	3369	3728	455	11	0	2,0		
Nursery								
Other permanent crops								
Greenhouse tree crops								
Mushrooms								
Greenhouses[6]								
Total	327	7422		23	149	1,9	205	9435

1 In line with CHG (2008b), TOP region is the Tinto, Odiel and Piedras river basin complementary region.
2 Total economic value (total €) divided by area (ha)
3 Source: MAPA (2002)
4 Economic value (€/ton) multiplied by production (ton/year). Source: MAPA (2002)
5 Total economic value (total €) divided by the total use of water resources (m3/year)
6 Gross Value Added (GVA). Source: CHG (2008b)
7 Source: CHG (2008b)
8 Grain cereals comprise main cereals in the area according to MAPA 1T sheets.

	Economic value					Water economic productivity[5]	GVA[6]	Employment[7]
D) LOWER GUADIANA[1]	€/ha[2]	€/ha[2]	€/ton[3]	Total million €[4]		€/m[3]	million €	post number
Crop	Rainfed	Irrigated		Rainfed	Irrigated	Irrigated		
Grain cereals[8] – Wheat	325	457	133	2	0	0,2		
Grain legumes – Lupin, veza	129	276	190	0	0	0,1		
Potatoes	1767	2852	207	0	0	0,8		
Industrial crops – Sunflower		524	256		0	0,1		
Fodder – Veza and others			101					
Vegetables - Strawberries	0	28039	831	0	11	9,9		
Flowers and ornamental plants								
Seeds and small plants								
Other grass crops								
Fallow land								
Vegetable gardens								
Citrus		2961	192		5	0,5		
Temperate climate fruit trees								
Subtropical climate fruit trees								
Dry fruit trees								
Olive tree	428	786	498	2	0	0,5		
Vineyard	3369	3728	455	0	1	2,0		
Nursery								
Other permanent crops								
Greenhouse tree crops								
Mushrooms								
Greenhouses[6]								
Total	174	4765		5	17	1,3	45	2206

1 The Lower Guadiana basin comprises the Guadiana basin part in Huelva.
2 Total economic value (total €) divided by area (ha)
3 Source: MAPA (2002)
4 Economic value (€/ton) multiplied by production (ton/year). Source: MAPA (2002)
5 Total economic value (total €) divided by the total use of water resources (m3/year)
6 Gross Value Added (GVA). Source: CHG (2008b)
7 Source: CHG (2008b)
8 Grain cereals comprise main cereals in the area according to MAPA 1T sheets.