Chapter 9

The extended water footprint of the Guadiana river basin

Maite Aldaya & M. Ramón Llamas
Water Observatory of the Botín Foundation;
Department of Geodynamics,
Complutense University of Madrid, Madrid, Spain

ABSTRACT: The present analysis is focused on the Spanish side of the semi-arid, transboundary Guadiana river basin. In the basin, the main consuming sector for green water (rainwater stored in the soil as soil moisture) and blue water (surface water and groundwater) is agriculture, accounting for about 95% of total water consumption. Within this sector, high virtual-water crops with low economic values are widespread in the studied Upper and Middle Guadiana regions, particularly 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 Tinto, Odiel and Piedras (TOP) river basins domain, where vegetables and crops are grown under plastic, the blue water economic productivity values are much higher, using both surface water and groundwater resources. The quantity of crops and the amount of employment generated in the whole Guadiana basin are already producing *more crops and jobs per drop*. The aim now is to move towards a policy of *more cash and nature per drop*, especially in the Upper and Middle Guadiana basin.

Keywords: Guadiana river basin, extended water footprint, green water, blue water, virtual water trade, economic water productivity

1 INTRODUCTION

This chapter presents the general and synthetic view of the authors on the use of the extended water footprint for the assessment of the water policy in the Guadiana Basin in Spain. Only three references are provided, where more detailed information can be found.

Today most water resources experts admit that water conflicts are not caused just by water scarcity, but are mainly due to poor water management. Water resources management has inherently a socio-political and economic nature. In this context, virtual water and water footprint analyses link a large range of sectors and issues and provide a transparent framework to find potential solutions, and contribute to a better management of water resources, particularly in water-scarce countries. As the most arid country in the European Union, water use and management in Spain is a hot political and social topic. The semiarid and transboundary Guadiana river basin, located in South-central Spain and Portugal, is among the most significant in Spain in terms of conflicts between agriculture and the environment (Aldaya & Llamas, 2009).

The present study deals with the analysis of the water footprint and virtual water trade of the Spanish part of the Guadiana river basin. The study considers the ways in which both green and blue (ground and surface) water are used by the different economic sectors. This could provide a transparent interdisciplinary framework for policy formulation and ultimately facilitate a more efficient allocation and use of water resources facilitating the achievement of the European Water Framework Directive objectives.

2 STUDY AREA

The Guadiana basin has an area of 66,800 km^2 (83% in Spain and 17% in Portugal). For practical purposes, the basin has been divided into four areas (Figure 1). These are: a) the groundwater-based Upper Guadiana basin (entirely located in the Castilla-La Mancha Autonomous Region); b) the 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 Upper Guadiana basin is one of the driest river basins in Spain. 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. These wetlands provided crucial nesting and feeding grounds for European migrating bird populations and were home to rare animal and plant species. Today, the Tablas de Daimiel National Park (2,000 ha), a Ramsar Site, which used to receive the natural discharge from the

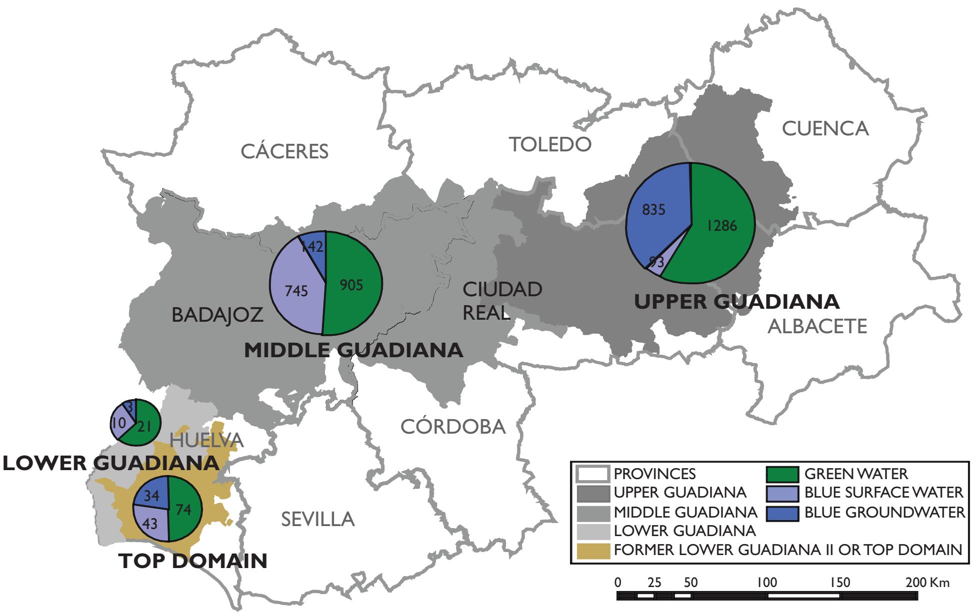

Figure 1 Agricultural use of water resources in the Guadiana (hm^3/year) (2001). (Source: Own elaboration).

Western Mancha aquifer, survives artificially, in a kind of *ecological coma*, thanks to the water transfers that have been coming from the Tagus-Segura Aqueduct since 1988 and to the artificial pumpage of groundwater from the aquifer that keeps about 5% of the 2,000 ha of wetlands in the Park flooded. In recent years, the situation has improved slightly since the 2010/2011 high rainfall years and the increase in electricity costs.

3 METHODOLOGY

The water footprint and virtual water trade are calculated using the methodology developed by Hoekstra and co-workers at the University of Twente. The method and data sources are described in more detail in Aldaya & Llamas (2008; 2009). The green and blue water are analyzed for each section of the basin (Upper, Middle, Lower Guadiana and TOP domain) over three different time periods – during an average year (2001), a dry year (2005), and a humid year (1997).

4 HYDROLOGIC RESULTS

4.1 Total water use in the basin

As in most arid and semi-arid regions, in the Guadiana river basin the main sector consuming green water and blue water is agriculture, which accounts for about 95% of total water consumption in the basin as a whole (Table 1). The next-largest blue water user is the urban water supply, which uses less than 5% of the amount of water used in agriculture, most of it returning to the system with lower quality. However, the security of this supply is extremely relevant from a political and economic point of view. Concerning the Andalusian part (Lower Guadiana and TOP domain), agriculture consumes a smaller proportion of water (about 75–80%), which accounts for the increase in the proportion attributed to the urban water supply. The industrial sector, even if it is the smallest water user, represents the highest economic value in terms of Gross Value Added (GVA), which refers to the value of goods and services produced in an economy (see Glossary). Agriculture is also a significant economic activity in the Guadiana river basin, being the most

Table 1 Water footprint of the Guadiana river basin from the production perspective (2001).

Population	*Water footprint related to production*	*Green*	*Blue*	*Total*	*Per capita*	*GVA*	*Water economic productivity*
		hm³/year			*(m³/cap/year)*	*(M€)*	*(€/m³)*
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	0.99
	Industrial		20	20	14	1,557	77.90
	Total	2,212	1,999	4,211	2,970	3,068	1.53

Source: Aldaya & Llamas (2009).

[hm^3 = cubic hectometre = million m^3 = 10^6 m^3].

important share of the GVA after the industrial sector (Table 1). 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.

As shown in Figure 1, 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. The Lower Guadiana basin and TOP domain combine both ground and surface water strategies.

4.2 Water footprints of crops (m^3/t)

In the basin, 19% of the crop area is devoted to irrigated agriculture; cereals, vineyards and olive trees dominate in the Upper and Middle Guadiana basins, whereas citrus trees and vegetables are more prevalent in the Lower Guadiana and TOP domain. When looking at rainfed agriculture, mainly cereals, olive trees and vineyards are grown in the basin.

When looking at the water footprint of crops, among the studied crops, industrial crops (e.g. sunflowers), grain legumes, grain cereals (1,000–1,300 m^3/t) [t = tonne = 10^3 kg] and olive trees (1,000–1,500 m^3/t) show the highest values. In humid years, however, olive trees are mainly based on green water resources. Even if olive trees (and vineyards) were traditionally rainfed crops, in recent years the irrigated area seems to have significantly increased for both crops.

It is widely believed that maize and vegetables are water-wasteful in terms of m^3/ha. Nevertheless, when looking at the virtual water content (m^3/kg), these crops consume less water than is generally believed. Among the studied crops, vegetables (100–200 m^3/t) show the smallest virtual water content figures, probably due to the high yields they have.

Vineyards have intermediate virtual water contents, of about 300–600 m^3/t. This is largely due to high yields. However, cereals are harvested with high dry matter and low (real) water content, whereas in the case of melons and tomatoes the real water content values are very high.

Despite the semi-arid nature of the Guadiana basin, in the Upper and Middle Guadiana basin, irrigated grain cereal production was widespread in the year 2001. Aside from cereals, vineyards and olive trees were the most widespread crop in the basin that year. Two reasons may explain this trend. First, vineyards are significantly water-efficient (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 the largest part of the irrigated area and represent the highest total economic values in this region.

5 ECONOMIC RESULTS

5.1 Agricultural economic productivity (€/ha)

As it is widely known, the economic productivity of irrigated agriculture, defined as the market value per hectare, is higher than that of rainfed agriculture. In the case of the Guadiana basin this is true for any type of year (average, humid or 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. 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.

5.2 Economic blue water productivity (€/m^3)

The Andalusian part (i.e. Lower Guadiana and TOP), with a joint surface and groundwater use, has the highest agricultural water economic productivity due to the high economic value of the vegetables which are widespread in this region. 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.

When looking at the productivity per crop type in the Guadiana basin (Figure 2), vegetables (including horticultural and greenhouse crops) present the highest economic value per water unit (amounting to 15 €/m^3 in the Andalusian part, i.e. the Lower Guadiana and TOP domain). With lower values vineyards (1–3 €/m^3), potatoes (0.50–1.50 €/m^3), olive trees (0.50–1 €/m^3) and citrus trees (0.30–0.90 €/m^3) show intermediate values. Finally, with remarkably lower values, grain cereals, grain legumes and industrial crops display an average productivity of less than 0.30 €/m^3. These data show that the problem in the Guadiana basin is not water scarcity but the use of large amounts of blue water for low value crops (about 40% in 2001).

The nutritional productivity provides a different picture, wheat having a significantly higher calorific value (2–2.5 Kcal/L) than 1 kg of potatoes (2 Kcal/L) and vegetables (0.3–1 Kcal/L).

5.3 Agricultural trade

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

The province of Badajoz (Middle Guadiana) is a net canned-tomato exporter, while importing other commodities such as cereals (Aldaya & Llamas, 2009). The increase in cereal imports in drier years has to be highlighted.

Huelva (Lower Guadiana and TOP domain) also imports virtual-water-intense commodities, such as cereals, whereas it exports low virtual water content fruits. The drier the year, the higher the cereal imports. In hydrologic terms, importing virtual water through cereals saves 1,015 hm^3 in Huelva, whereas growing vegetables for

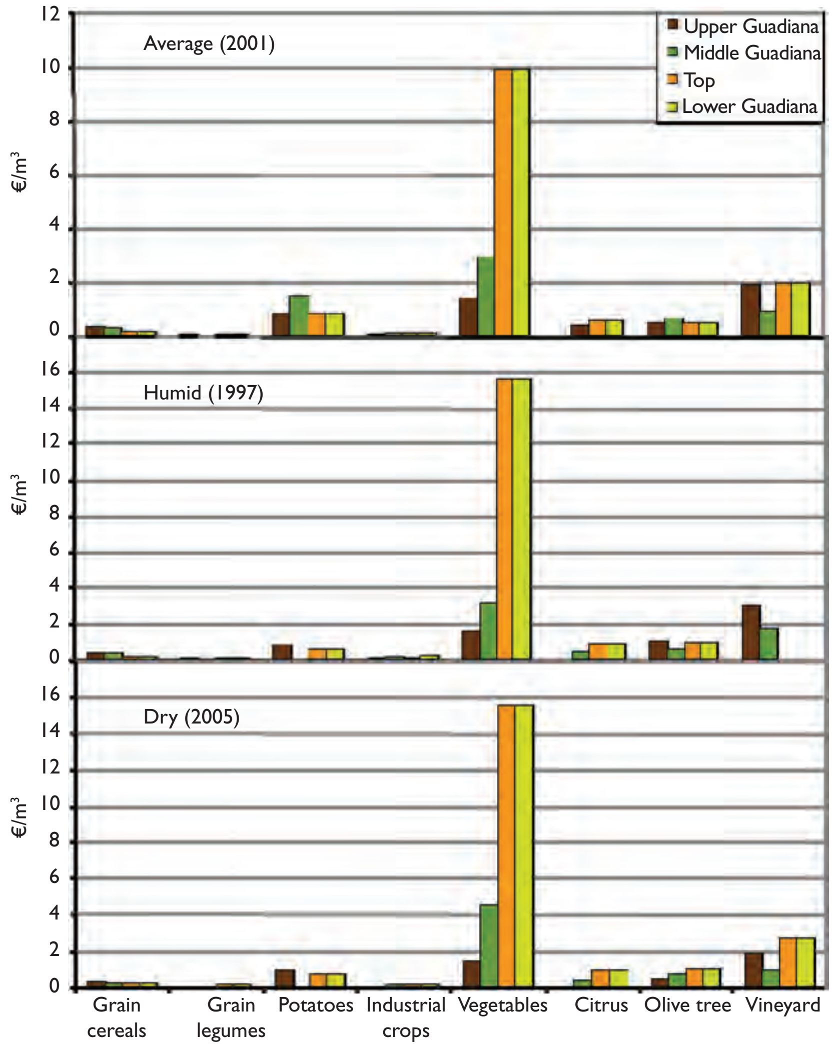

Figure 2 Blue water economic productivity (€/m³) concerning agricultural water consumption by crop and year in the Upper, Middle and Lower Guadiana and TOP domain. (Source: Aldaya & Llamas (2009)).

export uses just 100 hm³. 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, can 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). 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 the exchange of goods, diversification of crops, diet awareness raising or crop replacement measures.

6 POLICY IMPLICATIONS

It is important to consider the long-term impact of water management practices in the Guadiana river basin following the WFD emphasis to attain a *good ecological status* of surface and groundwater bodies by 2015. The 2008 regulation transposing the WFD in Spain, including the water footprint assessment of the different socio-economic sectors in the River Basin Management Plans (Official State Gazette, 2008), could provide a transparent framework for a more integrated water resources management in the basin. In any case, the ongoing water management problems in the basin, particularly in the Upper Guadiana, mean that the goals set by the WFD are unlikely to be achieved within the required timescale.

To find a solution to the problems in the basin, the Ministry of the Environment developed a Special Plan for the Upper Guadiana Basin (PEAG). Chapter 20 on The Tablas de Daimiel deals in more detail with this topic. The plan is endorsed with 5,500 M€ over about 20 years (2008–2027), and incorporates actions such as the purchase of land and water rights from irrigators, or the closure (or legalization) of unlicensed wells. Complementary measures include reforestation and dryland farming. The plan devises a water consumption scenario that is compatible with a mid-term water table recovery (before 2027) and identifies water management tools to deal with the Upper Guadiana groundwater crisis. Among the mechanisms for the rearrangement of the water use rights aimed at environmental remediation of aquifers, the PEAG approves the acquisition of private rights of water use. In theory part of the rights acquired by the Hydraulic Administration will be for environmental uses (70%) and the rest (30%) transferred to the Autonomous Community for regulating this situation. Initially the target has been for social purposes. Unfortunately for the moment the Plan has not been fully implemented due to the economic crisis Spain is undergoing and the rights used for the environment have been less than 30%, meaning that any significant short-term progress is doubtful. In this context, policy makers will most probably do what their constituency wants. It is therefore crucial to focus on raising awareness and capacity-building among the population.

7 CONCLUSIONS

In the Guadiana river basin the main green and blue water consuming sector is agriculture, with 95% of total water consumption. Urban water supply and industry values have higher blue water economic productivity values than 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 (t/ha) and total production (t/year) of rainfed agriculture are notably lower than that of irrigated agriculture. Thus, even if it is less extensive, irrigated agriculture produces more tonnes and euros than rainfed agriculture.

As a whole, high-virtual-water low-economic value crops are widespread in the Upper and Middle Guadiana regions. For instance, cereals exhibit virtual water values of

1,000–1,300 m^3/t, and maize and vegetables (mainly tomatoes and melons) present the smallest values with around 600 and 100–200 m^3/t respectively, due to their high yields.

The economic productivity of blue water use in the Upper and Middle Guadiana basin ranges between 0.10–0.20 €/m^3 for low-cost cereals and 1.50–4.50 €/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 both surface water and groundwater resources, this value can amount to 15 €/m^3. Even with lower figures, vineyards (1–3 €/m^3) and olive trees (0.50–1 €/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.

Nevertheless, we should not over-simplify the issue by assuming that all the water that is not used for vegetables or trees is wasted water. Factors such as risk diversification, labour, market access 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 quantity 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.

Finally, the report provides a first estimation of trade in agricultural products by considering international imports and exports at a provincial level. The Upper Guadiana basin is a net exporter, mainly of wine, barely importing any food commodity; while the Lower Guadiana and TOP domain import low-value, high water-consuming cereals, and export high-value, low virtual-water content crops such as fruits. This reduces the demand on local water resources that can be used to provide ecological services and other more profitable uses.

These results and concepts are in line with the actions and measures envisaged in the Special Plan for the Upper Guadiana Basin. Their implementation such as rearrangements of the water use rights aimed at environmental remediation of aquifers, would make possible a mid-term water table recovery.

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