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Water value, water demand and WFD implementation in an olive intensive Guadalquivir SUB-BASIN

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Abstract. Guadalbullon river sub-basin belongs to the Guadalquivir basin and is an example of intensive olive cultivation. The value of water in the sub-basin is analyzed under different scenarios by integrating an agronomic model (water production function of olive), an economic model of farm results and a sub-basin hydrologic model of water use and river flow. The result shows that the value of water for olive oil production (net margin per m^3) is in the range of 0.60 €/m^3 – 2.0 €/m^3. The impact of minimum flow requirement constraints supposes a reduction of the gross added value of the irrigated olives equalling some 1.2 million Euros per year at sub-basin level.

Keywords. Water value – Ecological flow – Olive tree irrigation – Water framework directive.

Valeur de l'eau, demande en eau et application de la Directive Cadre sur l'Eau dans un sous-bassin du Guadalquivir avec culture intensive de l'olivier

Résumé. *Le sous-bassin de Guadalbullon relève du bassin du Gudalquivir et il constitue un exemple de culture intensive de l'olivier. La valeur de l'eau dans le sous-bassin est analysée en prenant en compte différents cas de figure qui intègrent un modèle agronomique (fonction de la production de l'eau sur olivier), un modèle économique des résultats de l'exploitation et un modèle hydrologique de l'utilisation de l'eau et du débit du fleuve dans le sous-bassin. Les résultats montrent que la valeur de l'eau pour la production de l'huile d'olive(marge nette par* m^3*) se situe entre 0,60 €/*m^3 *et 2,0 €/*m^3*. L'impact de la contrainte du débit minimum implique une réduction de la valeur ajoutée brute des oliviers irrigués qui s'élève à 1,2 millions d'Euros par an à l'échelle du sous-bassin.*

Mots-clés. *Valeur de l'eau – Débit écologique – Irrigation de l'olivier – Directive Cadre sur l'Eau.*

I – Introduction

In developed countries, water scarcity[1] is generally a consequence of the demand for economic uses which is higher than the available supply; this is frequent in the Mediterranean countries as water resources (surface and groundwater) cannot satisfy economic uses (agriculture, urban, industry and the services) and environmental flows. In the Guadalquivir Basin, in Southern Spain, as in most Mediterranean regions, the main use of water is irrigation. Analysis of water balance since 1992 has shown that percentages of use by sector have not changed significantly with industry representing 2% of the total volume; urban (domestic and services) 13% and agriculture up to 85% (mainly irrigation).

The importance of the irrigation on water use is around 6.5 times increase in the productivity of rain fed land, measured by Gross Value Added per hectare (GVA), and about 4.4 times measured as Net Margin for irrigated lands versus rain-fed crops. Irrigation in agriculture is an essential generator of wealth and an important rural development stimulator in the region. At present, in the Guadalquivir RB, 25% of the agricultural area is irrigated and produces 61% of the agricultural GVA in Guadalquivir. Scenarios for 2015 evolution of Guadalquivir agricultures project that the percentage of agricultural GVA produced by irrigation will reach 70% of the total basin agricultural GVA, which points out two ideas: first, the increasing strategic importance of irrigation for the regional economy and second the evolution towards a growing intensity in farm production and an increased value of irrigated farming.

Guadalquivir, with around 800,000 ha irrigated, is an example of a mature basin where the strategy of increasing supply was over in the 90's, with the possibility of new dams officially finished, and the focus turned to saving and efficiency in water management, which is now under implementation.

The Water Framework Directive (WFD) is an environmental norm and its main purpose is the sustainability of water by a long-term protection of resources; however, the scarcity of the resource implies the need to balance environmental protection with regional development (Water Act Art 40). Since the approval of WFD (2000) in Spain, the increasing water demand has produced a more intense struggle between industrial and commercial consumers and a global alarm because of environmental problems.

Currently, the water policy debate has started public participation in policies for allowing flexibility of water allocation through administrative measures and water markets. The public participation around the allocation of water to economic vs. environmental uses, and between different economic sectors might be supported with the tool of water's valuation. Irrigation of olive for oil production is probably the most recent driver on increasing pressure on water resources as irrigated olives have grown from zero in the 80's to almost 50% of irrigated land in the basin in the last 25 years (close to 400000 ha).

This paper illustrates the value of water for irrigation in an olive intensive sub-basin which is the Guadalbullon Sub-basin, in the Guadalquivir River Basin.

1. Case study

The Guadalquivir river basin in southern Spain has a surface of 57,527 Km^2 and a population of more than 4.2 million people in 476 municipalities. The Hydrological Plan for Guadalquivir outlines the general management of the basin and indicates that the average basin's renewable water resources (surface and groundwater) are around 6,300 hm^3/year (Ministerio de Medio Ambiente, 2006), while the 'unrestricted' gross consumption for 2002 was estimated at 3.583 hm^3/year (82% surface and 18% groundwater). The basin is highly regulated, and irrigation depends upon reservoirs regulating 35% of natural superficial resources. The level of water abstracted is high and rainfall fluctuates; therefore, the guarantee for accomplishing user's water allocation rights is low. Agriculture with 86% of water use is by far the biggest consumer of water.

The irrigated area is currently 752000 ha and expected to be 800000 by 2015. Water for this area originates from regulated rivers (49%), unregulated rivers (17%), groundwater (33%), and from the reuse of wastewater (2%). Six crops represent 89% of the irrigated area and 90% of water demand for irrigation. Regarding the irrigated land, olive tree covers 42% of the area (39% of water use), cotton 9% (12% of water use); rice 5% (17% of water use); maize 7% (11% of water); winter cereals (mainly wheat) 7% (4% of water) and vegetables 6% (7% of water).

Water availability patterns in semiarid regions are extremely variable. Even in basins with a highly developed infrastructure, users are subject to unreliable water supplies, incurring in substantial economic losses during periods of scarcity. The Reform of the Spanish Water Law (Law 1/2001) allows for water markets between users with active water rights (to avoid new entrants that have not been previously under Water Agency control). Most of the water rights in Spain belong to user associations, mostly collective organizations (with a greater presence for surface water). The last severe drought urged the Government to promote additional reforms of the Water Law supporting Water Banks and allowing for water transfer between basins.

The main characteristics of agriculture evolution in the years 1992- 2005 are the decrease in rain-fed land (400000 has), and in the number of farms (average farm size from 13.45 ha to

19.94 ha.) Another key factor is the important increase in the olive growing area that is now the most important crop with 41% of the total agricultural area, 42% of irrigation and 35% of water consumption.

The current policy in the basin is to improve irrigation systems, (changing to trickle irrigation) and also to improve the distribution system level (pressurized networks). Each farmer receives an amount of water assigned by the water authority as a ‘water right’ or concession. Water concessions are usually assigned for a ‘standard year’ at 6000 m^3/ha; however, in the Guadalquivir, they rarely receive the full right and are often allowed to use only a much smaller allocation. It should be noted that the amount of 6000 m^3/ha is an average from the different administrative allocations that varies according to both area and crops (e.g. rice receives around 12000 m^3/ha while some olive growing areas 2500 m^3/ha). Evolution of allocated water for irrigation has decreased continuously during the last 20 years from 7000 m^3/ha in the 80’s to 5000 m^3/ha average in 2000-2005.

Irrigation water supply has the lowest priority (it can be considered as the ‘residual’ use) because water for agriculture will be the last to be allocated after the top priority uses are fully satisfied (urban, environmental minimum flow). The use of water in the Guadalquivir Basin for the currently irrigated 752000 ha[2] is based on administratively assigned water rights equal to 3.365 hm^3; however, this level of water use implies that crops do not receive the optimum water supply as the resources are lower than the theoretical irrigation needs for a normal hydrological year (computed according to Penman’s ETP) and estimated as 3.857 hm^3. Therefore, even in a good hydrological year (unrestricted supply of administrative water rights) irrigated agriculture cannot use of total demanded water (deficit irrigation).

The environmental flow is defined as a ‘constraint’ upon the rest of economic uses (Water Act 11/2005). The purposes of the environmental flows are: (a) to provide habitat conditions for flora and fauna; (b) to provide temporary regime of flows. Models are adapted to intermittent rivers, seasonal rivers and estuaries, as well as heavily modified water masses. In Guadalquivir River, environmental flows were made for two seasons: humid (Dec. - April) and dry (May- Nov.)

The case study focused on Guadalbullon Sub-basin that is a good example of olive irrigation supplied by an unregulated river. Agricultural area in this sub-basin is 70,494 ha, with 21,479 (30%) irrigated. The most important crop is olive tree, with 91% of the total rain-fed cultivated area and 86% of the irrigated area (30% of olive groves are irrigated in this sub-basin). The rest of the area is grown with cereals, 4% of the area (16% is irrigated, 2% of the total irrigated lands); industrial crops, potatoes and vegetables (2% respectively) standing for the remaining 6% of the total cultivated area and 10% of irrigated lands.

Additionally to irrigation, the sub-basin water consumption is reported in table 1 showing that ‘unrestricted’ water rights in agriculture would use, in a good hydrological year, 70% of water in the basin (59.3 hm^3), but practically the real yearly average use is around 41 hm^3. An average irrigation/year takes 69% of the ‘administrative water rights’.

The basin uses more water than the sustainable amount and the consequence is that the environmental flow is not respected and during around 10 days per year the river is dry (no water in the river). This is a social and environmental undesirable situation and requires some water saving measures. Nevertheless, opportunities for water saving in non-irrigation sectors (urban, industry) are a few and the significant savings should be mainly focused on controlling irrigation.

Table 1. Summary of water consumption.

Use	2005 Consumption (hm3)	GVA (x 1.000 €)	Main variable
Urban- Domestic	18.38	18.380	Population 158.453
Industrial	3.85	9.716.093	
Agrarian(1)	59.31	66.872	21.541 ha irrigated
Livestock	0.74	n/d	10.228 Livestock units
TOTAL	78.63	9.801.345	

(1) Administrative water rights.
Source: Draft Program of Measures- Confederación Hidrografica del Guadalquivir (2008).

Table 1 shows that the administrative water rights total 78.6 hm^3 which supposes 66% of the estimated renewable resources in the basin equalling 121.8 hm^3 (CHG-MMA Draft Hydrological Plan, 2008). The literature suggests that an extraction of water over 40% of renewable resources may be a target for a sustainable management of resources, but this is not a 'legal target' or constraint because the current legal constraint is the minimum environmental flow that is defined for this sub-basin in the level of 700 l/s (July-January) and 1.420 l/s (February-June).

The following section analyzes the value of water as an indicator of water demand for the implementation of economic instruments to control water consumption in accordance with WFD regulations.

II – Methods

This research tries to valuate irrigation water for olive groves and analyze the consequences of this valuation for the implementation of WFD and the achievement of sustainable management. As to the valuation of irrigation water, Young (2005) offers a complete revision of available methods. This research selects the production function method which is deductive based upon the integration of three models:

Agronomical: Production function

Financial: Profitability analysis of farms

Hydrological: Annual availability of irrigation water.

The first model is based on Moriana *et al.* (2003) who obtained the following production function for an olive grove for the years 1996-99 in Cordoba (Spain).

$$q = -2{,}78 + 0{,}011ET - 0{,}006 * 10^{-3} ET^2 \qquad R^2 = 0{,}59 \qquad (1)$$

Where:

q = Oil production, in metric tons per hectare

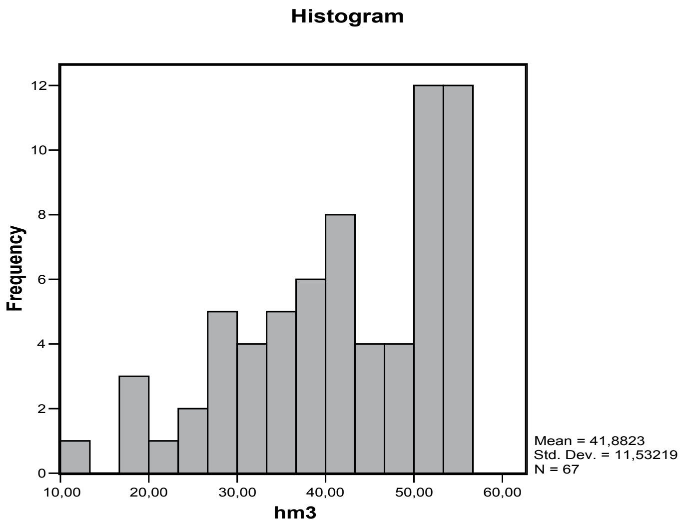
ET = evapotranspiration, in millimetres

This function is based on ET, and should be related to net irrigation. For this calculation, the effective rain is estimated as 70% of rainfall (Pastor *et al.*, 1999). The olive oil production is converted into financial returns by integrating the income and cost analysis for the crop in this area. This will be done for the present and future scenarios, specifically:

– Scenario 2005 is defined with the CAP subsidies and prices previous to the last reform. The financial model is based on data obtained from Farm Accountancy Data Network (FADN).

– Scenario 2015 is obtained with the new aids and prices scenarios. A tendency scenario is considered from the compiled data of the consulted sources (European Comission, OECD-FAO, FAPRI, USDA). For further details, it is recommended to consult Mesa-Jurado *et al.* (2008), where the different indicators used to construct this scenario are described. Water cost is variable, since it depends on the used volume; also, in the specific case of this sub-basin, it was necessary to input the cost of a recently-made pond.

Finally, to know the unrestricted and average use of water, the hydrological model simulates the last 67 years with the available climatic data and extrapolates irrigation water use once the priority uses are satisfied (domestic, industrial, livestock and environmental flow). The result is shown in figure 1 where the irregularity of water resources can be appreciated.



Observations		67
Average (hm3)		41,9
Median (hm3)		43,0
Mode (hm3) 5		5,7
Percentages		
	10	24,4
	20	30,8
	25	34,3
	30	36,4
	40	40,0
	50	43,0
	60	48,4
	70	51,6
	75	52,7
	80	53,0
	90	55,6

Source: Own elaboration based on Guadalgua.OPH-CHG data
Figure 1. Guadalbullon RB Irrigation supply histogram (hm3).

WFD working procedures aim to reach good environmental status for the year 2015; therefore, there is a need to analyze the 2015 demand scenario. This research will use the following scenarios.

– Water supply is equal to unrestricted authorized uses (59.3 hm^3)

– Water supply is equal to average supply without respecting environmental flows (41.8 hm^3)

– Water supply is equal to average supply respecting environmental flows (39.6 hm^3)

– Water supply is equal to average supply respecting environmental flows (39.63/2 = 19,81hm^3)

– No irrigation (W = 0)

The following section applies the methodology to the available data.

III – Results

Using the production function [1], price of oil and production cost, the net margin (NM) related to irrigation water is computed in [2].

$$\mathbf{NM = (p\text{-}k_1)\ Q - CF} \qquad (2)$$

Where:

NM: Net Profit, expressed in euros per hectare

p: price of the olive, expressed in euros per kilogram. For the year 2005, the average price was 0.49 €/kg., with an estimated value of 0,51 €/kg for the scenario 2015.

k_1: variable costs coefficient. Values used in the study are k_1: 0.1558 for the year 2005 and 0.1667 for the year 2015[3]

Q: olive production, in kilograms per hectare

CF: fixed costs, in Euros per hectare. For this study case, the average value is 52 €/ha.

By replacing q, obtained from expression [1] we find that:

$$\mathbf{MN = (p\text{-}k1)\ (\text{-}2{,}78 + 0{,}011ET - 0{,}006{*}10\text{-}3ET2) + CF} \qquad (3)$$

Where: ET: evapotranspiration in millimetres

We have:

$$\mathbf{ET = R/10^4\text{-}PE}$$

Where:

R: Irrigation amount in cubic meters per hectare

PE: Effective rainfall in millimetres.

By taking derivative from irrigation, we get the following equation:

$$\mathbf{\Delta MN/\Delta\ rainfall = (p\text{-}k1)0{,}011 - (p\text{-}k1)0{,}012{*}10\text{-}3(R/10\text{-}PE)} \qquad (4)$$

Equation [4] is a linear function that depends only on the irrigation amount, and where the rest of variables are taken as known and constant.

Results of the three models application are detailed in appendix 1. From these, the opportunity cost of establishing the environmental flow results in 56 €/ha (3315-3259), that is equivalent to 1.8% of the Net Margin for an irrigation farmer. At aggregate basin scale, it represents approximately 1,2 million Euro.

The following graph shows how the net profit would drop from 2005 to 2015 scenarios.

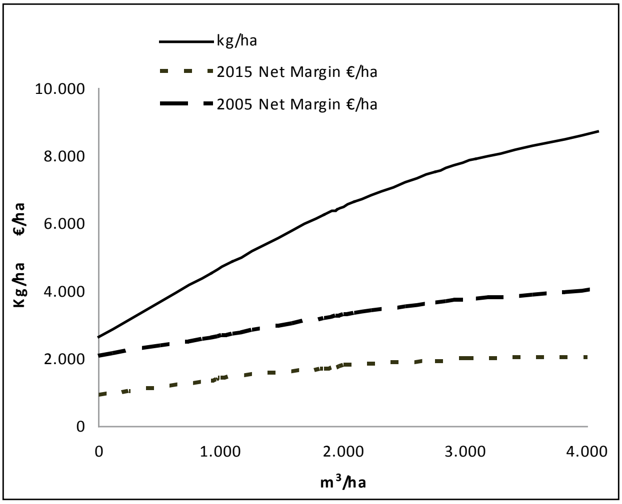


Figure 2. Assessment of irrigation value in olive tree production in Guadalbullón RB.

IV – Discussion and conclusions

The resulting water values can be compared to the ones from other studies; Berbel and Mesa (2007) obtained, through the Quasi-Hedonic Pricing Method, a value in the range of 0.14 to 0.35 €/m^3 for mills' of olives; Berbel and Pistón (2008) estimated an average of 0.19 €/m^3 through the Residual Value Method (not including the CAP aids). So, we conclude that the use of agronomical models shows higher values for water since the response of the olive grove to water is remarkably characteristic of this species.

With the production function form, it is advisable to make a detailed analysis of water value in marginal and not in average terms. When the opportunity cost for establishing the environmental flow, as marginal values are used instead of averages, the value of water increases and value in the margin goes from average value of 1.843 to marginal value of 1.948 m^3/ha, increasing the real financial opportunity cost of saving water to 0.54 €/m^3 or 57 € per ha.

Previous calculations make an estimation of approximately 1,2 million Euros as net profit lost by farmers; however, this loss should be compared to the gains in terms of welfare that the society gets from a better environment. This benefit should be quantified as the relation between it and the value that the society gets from the flow maintenance.

Finally, it is necessary to introduce the present research into Basin Plans and Cost-Effectiveness Analysis of Measures as presented by the WFD. Thus, we can compare the rise of welfare based on the improvement of river flows, to the decrease of the local agrarian sector production.

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[1] Shortage = Water demand over the available offer, what makes it necessary to use instalments or administrative systems to balance both of them. Drought = Drastic reduction of water offer that makes it necessary to apply exceptional measures. Rainfall is the atmosphere's water contribution as rain, snow or hail.

[2] Provisional data, the estimated figure is 751.785 ha for December 2007.

[3] In the year 2015, water cost is calculated based on the price of water, adding the cost of a pond. Then, the cost of water is: (0,0382+0,001+0,2) €/m^3*Total used water (m^3/ha)

[4] This is used to convert the irrigation units. It is changed from cubic meters to hectares per millimetre.

Appendix 1

Table A1 2005 Data.

	Hm³	m³/ha	mm ETP	Olive Kg./ha	Net Margin (€/ha)	Δ Net Margin (€/ha)	Paid Labour (€/ha)	Family Labour (€/ha)	Total Labour (€/ha)	GVA (€/ha)
Unirrigated	0	0	391	2.640	2.120	--	187	72	259	2.307
50% Available Uses	19,81	922	483	4.536	2.686	0,61	322	124	446	3.076
Available Average Use	39,63	1.843	575	6.250	3.259	0,62	443	171	614	3.770
No environmental flow	41,88	1.948	586	6.420	3.315	0,54	455	175	631	3.839
Authorized Uses	59,36	2.761	667	7.552	3.694	0,47	536	206	742	4.297

Tabe A2. 2015 Scenario Data

	Hm³	m³/ha	mm ETP	Olive Kg./ha	Net Margin (€/ha)	Δ Net Margin (€/ha)	Paid Labour (€/ha)	Family Labour (€/ha)	Total Labour (€/ha)	GVA (€/ha)
Unirrigated	0	0	391	2.640	905	--	187	72	259	1.092
50% Available uses	19,81	922	483	4.536	1.334	0,47	322	124	446	1.876
Available average use	39,63	1.843	575	6.250	1.701	0,40	443	171	614	2.585
No environmental flow	41,88	1.948	586	6.420	1.734	0,31	455	175	631	2.655
Authorized Uses	59,36	2.761	667	7.552	1.927	0,24	535	206	742	3.122