Agricultural Water Demand in Guadalquivir River (2005 Value *vs.* 2015 Scenario)

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Abstract— **This paper reviews the application of a scenario for the 2015 agricultural policy and markets for the irrigated agriculture in Europe. Scenarios for irrigated agriculture 2015 are described in detail including Reformed CAP and how biofuel impacts demand. A model for irrigation water demand is applied at the basin level for the Guadalquivir River (Southern Spain). The methodology is based upon residual value of water and it combines budget and farm analysis at municipality level, with the Guadalquivir basin divided at 50 counties where 24 possible crops are selected and adapted specifically to each county yield and costs. The result is a comparative analysis between actual level of water use and value, and 2015 scenario at county level and later aggregated at basin level.**

***Keywords*—**Irrigated agriculture, Value of water, Scenario analysis.

I. INTRODUCTION

Irrigation in Southern Europe is an indispensable input for agriculture as in most of the world arid and semiarid environments. In Mediterranean countries, irrigated farming accounts for a large share of total water withdrawals (83% in Greece, 68% in Spain, 57% in Italy, and 52% in Portugal). The irrigated area in the EU has grown from about 6,5 million hectares (Mha) in 1961 to nearly 12 Mha in 1996.

Current management of water resources is subject to uncertainty and scarcity and new institutions and technical tools are used, among them the implementation of Directive 2000/60/EC 'Water Framework Directive' (WFD) [1] in whose preamble states that water supplies to the population in most European countries are threatened by human-induced pressures and that aquatic ecosystems are undergoing severe processes of quality deterioration. As we will see below, reversing these trends is the main objective of the WFD.

WFD enhances the use of economic analysis of water resources and uses and it supports the achievement of economic objectives, specifically cost recovery for water services, including environmental and resource cost within each of the three sectors: agriculture, industry and domestic. The meaning of this sentence has been defined in detail in the WATECO guide (2003) [2] that develops the concept of full cost recovery based on the concept of cost recovery related to 'water services'.

In any case, WFD recognized the fact that water management should include economic analysis of alternatives. This is even more urgent in regions where water scarcity is a critical issue as it is in Mediterranean regions. This paper takes advantage of two economic instruments to study the demand of irrigated water in the Guadalquivir basin (Southern Spain).

The value for humans of any ecosystem goods or services (such as water or any other factor of production), is justified because they enter the utility function (Brown et al, 2006) [3]. The economic value of something is a measure of its contribution to human well-being. In economic theory, the value of water can be treated as an 'economic rent', i.e. it may be considered an input factor similar to land.

II. CASE STUDY

The case study *Guadalquivir River Basin* in southern Spain has a surface of 57.527 Km^2 and a population 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 6300 hm^3/year (MIMAM, 2006)[4], while the gross consumption for 2002 was estimated at 3583 hm³/year (82% surface and 18% groundwater).

The basin is highly regulated, and supply is supplemented with reservoirs regulating 35% of natural superficial resources as well as the base flow and exploitation of aquifers reaching 49% of renewable water resources. The level of water extracted is high and rainfall fluctuates; therefore, the guarantee for accomplishing user's water allocation rights is low. Agriculture is by far the biggest user of water (uses 86% of water in the basin) and the map shows where the main irrigated areas are located.

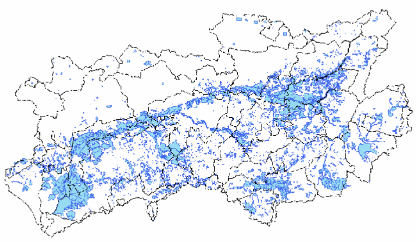

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Fig 1. Irrigated areas in Guadalquivir River (MIMAM, 2006).

Six crops represent 87% of irrigated area and 85% of irrigated water demand. Regarding irrigated area, olive tree uses 55% of area (39% of water use), cotton is 9% of area (12% in water use); rice 5% of area (17% of water); maize 7% of area (11% of water); sunflower 4% of area (2% of water); and winter cereals (mainly wheat) 7% of area (4% of water).

Current policy in the basin is to improve farm irrigation systems, (changing to trickle irrigation) and also 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 River they rarely receive the full right and are often allowed to use only a much smaller allocation.

III. THE METHOD OF RESIDUAL VALUE OF WATER

Natural resources are susceptible to be economically valuated. There is an ample source of information regarding to the valuation of irrigation water in which the presented methods, differ from each other in the approximation used as well in the results. We can find a revision for these methods in publications by Young (2005) [5], which are summarized in:

1. Residual value and derived methods.
2. Methods based on marginal productivity.
   - Works based in the production function
   - Econometric models
   - Mathematical Programming Methods
3. Other methodologies based on "Environmental Valuation".
   - Hedonic pricing.
   - Contingent valuation.

This paper uses the residual value of water for agriculture in the Guadalquivir in order to study allocation of the resource. Among the difficulties for implementing the technique we have the estimation of all costs and the existence of multi-output production systems. The hypotheses underlying the residual value method are part of the neoclassical economic theory, i.e. producers maximize profits and the total value of the product may be assigned to each input according to marginal productivity. The mathematical expression is shown in (1):

$$Y = f(X_M, X_H, X_K, X_L, X_W) \quad (1)$$

Where Y is output and it is a function of material inputs (X_M), human capital and labour, (X_H), built capital such as buildings, tools, roads, and vehicles (X_K), land, (X_L), and water (X_W). If we consider technology as constant but all factors variable, then we have the total value of production as:

$$(Y \cdot P_Y) = (VMP_M \cdot X_M) + (VMP_H \cdot X_H) + (VMP_K \cdot X_K) + (VMP_L \cdot X_L) + (VMP_W \cdot X_W) \quad (2)$$

Where $Y \cdot P_Y$ represents value of product Y; and VMP_i is the value of marginal product of each factor, i.e. we assume the hypothesis of the total value of the product may be assigned to each input according to marginal productivity. The other hypothesis is the profit maximizing behaviour, therefore we deduce the optimum solution as the point where farmer will consume each factor until $VMP_i = P_i$, so that we substitute P_i by VMP_i in equation.

$$(Y \cdot P_Y) = (P_M \cdot X_M) + (P_H \cdot X_H) + (P_K \cdot X_K) + (P_L \cdot X_L) + (P_W \cdot X_W) \quad (3)$$

If we are able to obtain a good estimation of all prices and uses of each factor, except water, we may estimate the value of water $(P_W \cdot X_W)$ as the only unknown variable in equation (3). As the water consumption per crop may be known for each location, we get the residual value of water as P_W :

$$P_W = \frac{(Y \cdot P_Y) - [(P_M \cdot X_M) + (P_H \cdot X_H) + (P_K \cdot X_K) + (P_L \cdot X_L)]}{X_W} \quad (4)$$

Expression (4) is the basis for the residual method (Young, 2005)[5] and finally we get the value of water (€/m^3). As we mention, the residual method estimates the value of water starting from expression (4). We compute all factors in a hectare basis, with a minor improvement shown in equation (5). This modification is necessary as the value of the water may be computed 'at source' or 'at farm', and we will use first alternative according to the expression:

$$R^{W1} = [Y \cdot P_Y] - [(P_M \cdot X_M) + (P_H \cdot X_H) + (P_K \cdot X_K) + (P_L \cdot X_L) + C + E] \quad (5)$$

If we divide the rent R^{W1} by W (water consumed per hectare) we get the average value of water (€/m^3.). Application of the model is quite straightforward, and next section shows the results for individual crops and the basin as a whole.

The basis for the distribution of value is based upon the fact that fixed factors are not paid by the marginal value of the productivity as it happens with variable factors (i.e. fertilizer, etc.). Friedman (1976) [6] summarises the key point for residual value method. The returns to the specialized factors are now 'rents' at least in part, and do not determine the price but are determined by it.

IV. BASELINE SCENARIO FOR 2015

Scenario analysis is not a tool for future prediction, on the contrary the objective of scenario analysis is to support the present decision making process by estimating possible evolutions of the world. We are interested in the analysis of irrigation water demand and water value evolution for 2015 horizon as that year is supposed to be a new framework after revision of present CAP normative that will be operating for the period 2007-2013.

There are many precedents for scenario analysis; we may quote Foresight Futures UK (Berkhout et al.[7], DTI: 1999 [8], 2002 [9]), Scenar 2020 (European Commission, 2007) [10], USDA *Agricultural Projections to 2017* (2008) [11], *Prospect for Agricultural Markets and Income (2006-2013) in the European Union* (European Commission, 2006) [12], *OECD-FAO Agricultural Outlook 2008-2017* (OCDE-FAO, 2008) [13], *Ethanol expansion in the United States* (USDA, 2007) [14], and WADI (Berbel and Gutierrez, 2004) [15].

Qualitative analysis implies the definition of driving forces and we found that crop plan and technology is defined by farmer expectations, which depends upon different policies in European Union.

The main factor is the Common Agricultural Policy design influenced by Environmental policies (especially Water Framework Directive) and determining farm behaviour through cross-compliance measures. Main external factors are EU Commercial Policy, both the Doha Round and WTO agreements and preferential trade with MERCOSUR, ACP, Mediterranean countries. Also the EU enlargement with integration of Eastern European countries will impact significantly to agricultural markets for 2015. Finally, Energy policy will affect significantly agricultural markets through fiscal policy on biofuels.

This qualitative scenario must be translated into quantitative parameters in order to proceed to modelling results. We have used Agricultural Outlook FAO-OCDE report [13] corrected by FAPRI *US and World Agricultural Outlook* (2008) [16] and USDA (2008) [11]. All of them agree in commodities price increase (e.g. wheat and maize increases by 13% and 46%, respectively, over 2005 levels); sunflower increases as the demand for biodiesel impacts this crop. Regarding inputs we consider the present trend observed by Eurostat and FAPRI (2008) [16], where we can see that energetic inputs have an important increase. We have considered a yield increase for some crops (0,8%, 0,4% and 0,4% annual increase in wheat, maize and sunflower respectively) and the trend in permanent crops area observed in (2001-2004). Next table illustrates price increases for main crops, inputs and other interest data:

Table 1: Quantitative parameters for baseline scenario 2015

Baseline			
% Increase 2005/2015			
Prices		**Input Prices**	
Wheat	113	Seed and plants	130
Maize	146	Energy	113
Rice	123	Fertilizers	135
Oil seed	173	Pesticides	113
Olive oil	104	Machinery	117
Linked subsidies	0	**Labour cost**	100

Unitary labour cost is supposed constant as increases in salary are compensated by productivity growth. Scenario 2015 assumes the total decoupling and for this year there are no subsidies linked to production and EU support is done directly. The "*CAP Health Check*" is supposed to reduce the farmer direct support by 13% and will derive this amount to support the CAP 2nd pillar.

Regarding local conditions, Guadalquivir irrigated area will grow 6% compared to 2005 situation due to the on-going irrigated areas under development. The new areas are to be used for tree crops (olive and citrus) and there will be a reduction in cotton, sugar beet and rice where wheat, sunflower and maize will take place, benefited by higher prices in commodities and the support by the Biofuel Directive 2003/30/CE [17].

V. RESULTS

Data for application of model is based upon secondary information for production functions, input and output prices, technical coefficients and crop cultivated areas, starting point for the residual value analysis is 2005.

For the aggregation of residual values at basin level we use 50 territorial units (counties which are around 10 municipalities each), each of these territorial unit has 24 possible crops so that we have 1200 possible residual values of water, but some of the crops are not cultivated in all the basin, as an example rice is only cultivated near the river estuary (4 counties), citrus is limited by climate to be cultivated only in 10 counties and olive is not possible in the lower river basin, so that finally we have around 600 residual values, each of them associated to a water consumption. We integrate this data to compute the aggregated water value vs. water consumed in the basin; this is shown in Fig. 2 below.

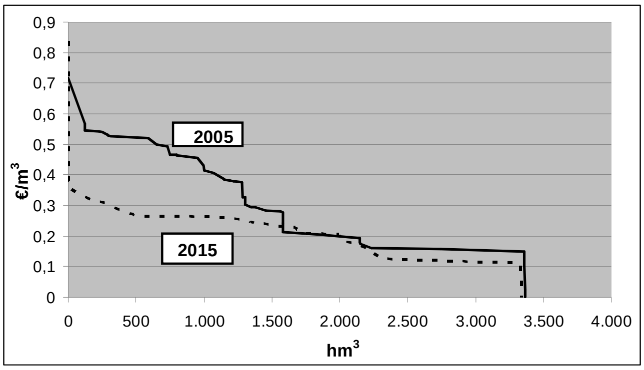

Fig 2. Residual value of irrigation water Guadalquivir 2005-2015 (Own elaboration based on MIMAM 2006 data)

The result is an average value of 0,31€/m^3 and 0,21€/m^3 for 2005 and 2015, respectively.

The basis for the model is the product exhaustion, i.e. what is defined in equation (5), and distribution of net margin between the production factors for 2005 is as follows: water takes 62%, land (rainfed value) is 20%, family labour is 8%, management 5% and owned capital is 4%. Value change in 2015 and they are 60% for water, land decreases to 15 %, family labour increases up to 11%, management 7% and owned capital is 7%. The Fig 3 below shows the change in the net margin distribution between production factors.

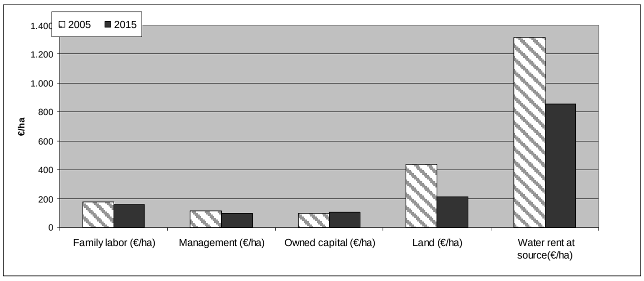

Fig 3.Distribution of Net Margin between the production factors for 2005 vs. 2015. (Own elaboration based on MIMAM data)

The figure above illustrates the reduction in economic margin (without Simple Payment) that implies a reduced value for each of the production factors, specially the land rent (rainfed) and the residual value of water as the other factors (labour, management, interest on owned capital) increase the return to its share of value.

Net margin is the value of agricultural production considering variable and fixed costs and it is the return of fixed factors (classically land, labour and capital). Fig. 4 illustrates the variation on agricultural economic indicators; Production Value increases due to a raise in prices and yields in most of the crops, although this does not result in higher profits since inputs' prices increase as well, so that said Net Margin remain approximately the same.

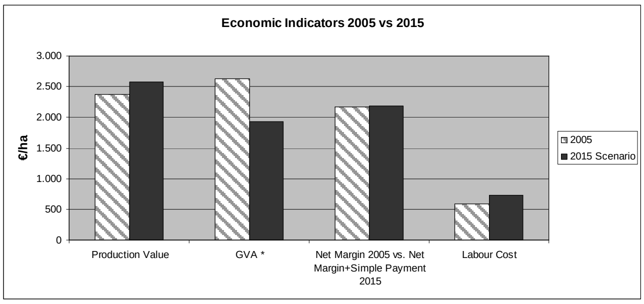

Fig 4. Comparison between economic indicators for 2005 vs. 2015 scenario (own elaboration based on MIMAM 2006 data).*GVA without subsidiaries

Fig 4 shows the comparison between [Net Margin (2005)] and [Net Margin + Simple Payment-2015] as a method to compare the household agricultural derived income. Scenario value for water decreases by 32%, so that theoretically the new CAP may reduce pressure on the resource. A weakness of the analysis is that we have supposed a growth in perennial crops according to a recent trend, which implies that the area of olive will increase by 40% and citrus by 25% for the period 2005-2015 by substituting herbaceous crops and occupying new irrigated areas. Therefore we assume that water moves from low-value crop (cereals) to high value (citrus and olives) but the hypothesis for scenario building has been that speed of transformation is similar to the recent past, but the growth in perennial crops might accelerated by the impact of reformed CAP.

VI. CONCLUDING REMARKS

We have presented in this paper the valuation of water under different scenarios. Aggregated basin value is given as the function relating water value (price) and irrigated consumption.

It can be emphasized that water's value is reduced as a result of the new agrarian policy; nevertheless, the demand remains the same. In the other hand, "potential" demand (the supply of water to crops, considering the maximum evapotranspiration) is beyond present supplies, and this situation persists in the 2015 trends scenario.

As a consequence, saving and efficiency measures being taken nowadays should start from the fact that present pressures on the use of water and short supplies will prevail in the future. This way, available resources in the basin, will keep being lower than the existing demand.

Finally, it is important to remark that the increase in production value is due to a raise in prices and yield in most of the crops, although this does not result in higher profits since inputs' prices increases as well, so that said profits remain approximately the same.

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REFERENCES

1. Directive 2000/60/EC of the European Parlament and of the Council establishing a Framework for the Community action in the field of Water Policy. Official Journal of European Union(OJ L 327) 22 December 2000.
2. WATECO (2003), Economics and the Environment. The Implementation Challenge of the Water

Framework Directive. Accompanying Documents to the Guidance, European Commission, Brussels.

3. Brown T.C., Bergstrom, J.C., Loomis, J.C. and Ft. Collins (2006), Ecosystem Goods and Services: Definition, Valuation and Provision. U.S. Forest Service. Discussion Papers RMRS-RWU-4851. 31 May 2006.
4. Ministeriode Medio Ambiente, Medio Rural y Marino at http://www.mma.es/
5. Young, R. A. (2005), Determining the economic value of water: concepts and methods. Washington, D.C.: Resources for the Future.
6. Friedman, M. (1976). Price theory. Chicago. Aldine Publishing Company. Page 147.
7. Berkhout, F. y Hertin, J. (2002), "Foresight futures scenarios. Developing and applying a participative strategic planning tool". Greener Management International, Vol. 37. 37-52.
8. DTI (1999): Environmental Futures. PB 4475 Department of Trade and Industry at http://www.foresight.gov.uk/.
9. DTI (2002): Foresight Futures 2020 Revised scenarios and guidance. Department of Trade and Industry, HMSO, UK.
10. European Commission (2007) Scenar 2020 – Scenario study on Agriculture and the Rural World at. http://www.ec.europa.eu/agriculture/publi/reports/scenar2020/

11 USDA (2008). Agricultural Projections to 2017. Office of the Chief Economist, World Agricultural Outlook Board, U.S. Department of Agriculture. Long-term Projections Report OCE-2008-1, 104 pp.

12. European Commission (2007): Prospect for Agricultural Markets and Income in the European Union 2006-2013.

13 OCDE-FAO (2008). Agricultural Outlook 2008-2017 at http://www.ocde.org/

14 Westcott, P.C. (2007): Ethanol Expansion in the United States. How will the Agricultural Sector Adjust? Economic Research Service, USDA, Washington D.C., FSD-07D-01.

15 Berbel, J. and Gutierrez, C. (ed.), (2004), Sustainability of European Irrigated Agriculture under Water Framework Directive and Agenda 2000. EUR 21220. Luxembourg: Office for Official Publications of the European Communities.

16 FAPRI (2008). U.S. and World Agricultural Outlook. Staff Report 08-FSR 1. Food and Agricultural Policy Research Institute, Iowa State University and the University of Missouri-Columbia.

17 Directive 2003/30/EC of the European Parliament and of the Council on the promotion of the use of biofuels or other renewable fuels for transport. Official Journal of European Union (OJ L123/42) 17 May 2003.

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