

ECONOMIC VALUE OF WATER IN AGRICULTURE: APPLICATION IN LAKE KARLA, GREECE

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ABSTRACT

The irrational use of water in agriculture is often responsible for several problems concerning the pollution or depletion of water resources. These problems must be confronted according to the principles of sustainability. Therefore, specific policy measures should be designed so as to protect water resources from harmful agricultural activities, mitigating at the same time their potential impact on agricultural development and on farmers' welfare. The application of economic measures, such as irrigation water pricing, may be conducive to this policy direction, by rationalizing farmers' behavior towards water consumption. The aim of the paper is to assess the economic value of irrigation water, the spatial variability of water values in the boundaries of a river basin, as well as the correlation of those values with significant changes in spatial demand for irrigation water. For these reasons, an indirect valuation method, called "change in net income" has been applied in the study area (Lake Karla, Greece). This method estimates the value of water according to the change in net income between the current irrigated crops and the most economic efficient scheme of dry farming. According to this methodology, the farmer's willingness to pay in a predefined increase in water quantity is considered equal to the change in farmer's income, resulting from this water increase. The irrigation needs of the crops were calculated using the index "Net Irrigation Requirement" (NIR). The result of this method is the estimation of the demand curve of the irrigation water, which graphically depicts the amount of water consumed by a farmer within a range of probable values. The final outcome of "change in net income" analysis displays the spatial variability of water values in Lake Karla Basin. These values fluctuate from 0.030 €/m³ up to 0.129 €/m³. The average value of irrigation water in the reference area was finally found equal to 0.062 €/m³. Finally, important conclusions resulted, regarding the probability of implementing a pricing policy of irrigation water in the future, as defined by the Water Framework Directive and the new national legislation. Such pricing should be based on prices that reflect the real value of the natural resource, in order to achieve the rational and effective use of irrigation water.

1 INTRODUCTION

Lake Karla basin is an intensely cultivated agricultural region. The intense and extensive cultivation of water demanding crops such as cotton has lead to a remarkable water demand increase, which is usually covered by the over-exploitation of groundwater resources. The aquifer of Lake Karla's basin, with an area of 500 km², is a prominent example of this unsustainable practice.

Up to 1962, a big lake existed at the southeast part of the Thessaly plain it was Lake Karla (the Voivis Lake of ancient Greeks), with a maximum size of 20,000 ha. The lake gave a fishproduction of about 1,000 tons annually thus sustaining 1,200 jobs and financially supporting equal in number families in the surrounding villages, where three fish-wharfs operated. It was also a very important wetland on a European level with more than 1,000,000 waterfowl hibernating in the lake's greater area.

In 1962 Lake Karla was drained through an ambitious reclamation project, mainly for agricultural purposes. Following its drainage, a part of the old lake-bed was cultivated with only mediocre results while fish production vanished, climate changed for the worse, the greater area's hydrological regime was severely disturbed with ground waters remarkably lowering, big cracks occurred at the soil and chemical degradation of the soil was detected. Quite shortly after the completion of the land reclamation project, it became evident that it was a failure, which created bigger problems than the ones it was supposed to solve.

The suggested plan for the restoration of Lake Karla started few years ago and it proposes the creation of a reservoir of 38 km² in the lowest part of the old lakebed, through the construction of two embankments, one in the eastern part and one in western part of the lake. This partial restoration is one of the most important hydraulic projects in the region, possibly in the whole country, and is expected to reverse the drawdown of the water table and other adverse environmental problems caused by the lake drainage. The Lake Karla's Partial Rehabilitation Project is an example project in the context of an effort to repair damages occurred due to the application of an unsustainable development model.

2 THE STUDY AREA

The watershed of Lake Karla is located in the eastern part of Thessaly in central Greece. The watershed is surrounded by Mount Kisavos to the northeast, the Mavrovouni Mountain to the east and south, and Pinios River to the northwest.

The natural basin of Karla had a total extent of 1,663 km² but after the construction of complimentary works, the drainage area of the restored lake Karla will be 1,171 km² (Loukas et al., 2008). Karla's aquifer area is about 500 km² (Figure 1). Most of the study area is plain with an altitude from 45 to 65 m. Only to the southwest the altitude reaches up to 90 m.

Thessaly plain is traversed by Pinios River and its waters are used primarily for irrigation. However, the overexploitation of the groundwater system has led to the deterioration of the already disturbed water balance and the degradation of the water resources. Over the years, various locations within Pinios river basin have been proposed for the creation of reservoirs, but only the dam of Smokovo has been recently constructed. The only other major surface water developments in Thessaly region are a

few small reservoirs and lagoons on or adjacent to Pinios river system and the diversion of water from the N. Plastiras reservoir, which is located outside of the Pinios River basin.

At the western and central side of Thessaly the climate is rather continental; the winter is cold and wet and the summer is hot and dry. At the eastern side of Thessaly the climate is typical Mediterranean. The average temperature is 16-17°C and the mean annual relative humidity is 67-72%. Most of the precipitation usually falls during the winter months and it is rare from June to August. However, the mountain areas receive significant snowfall during the winter months.

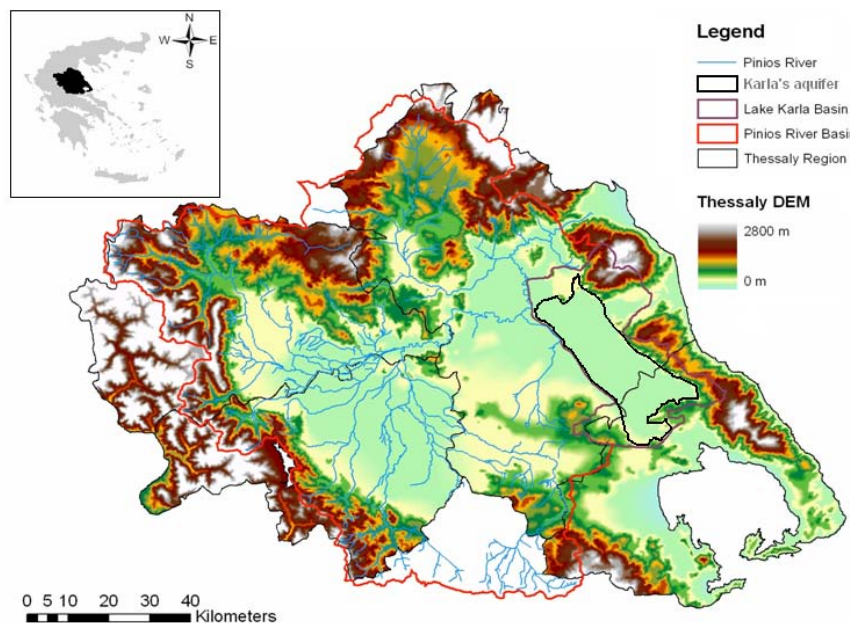


Figure 1: Map of the Region of Thessaly indicating the Lake Karla Basin.

Most of the study area is plain with an altitude from 45 to 65 m. To the east the Mavrovouni Mountain is placed which consists of impermeable bedrocks as schist. In the west continues the Thessaly plain except the southwest which the Halkodonion Mountain is placed.

The study focuses on the irrigated crops of four neighbouring municipalities of Lake Karla: Karla, Feres, Armenio and Kileler. In order to achieve more accurate results, the last two municipalities were divided into separate municipal departments: Sotirio, Armenio, Monastirio and Niki for the municipality of Armenio and Kileler, Agnanteri, Kalamaki and Melissa for the municipality of Kileler (Figure 2).

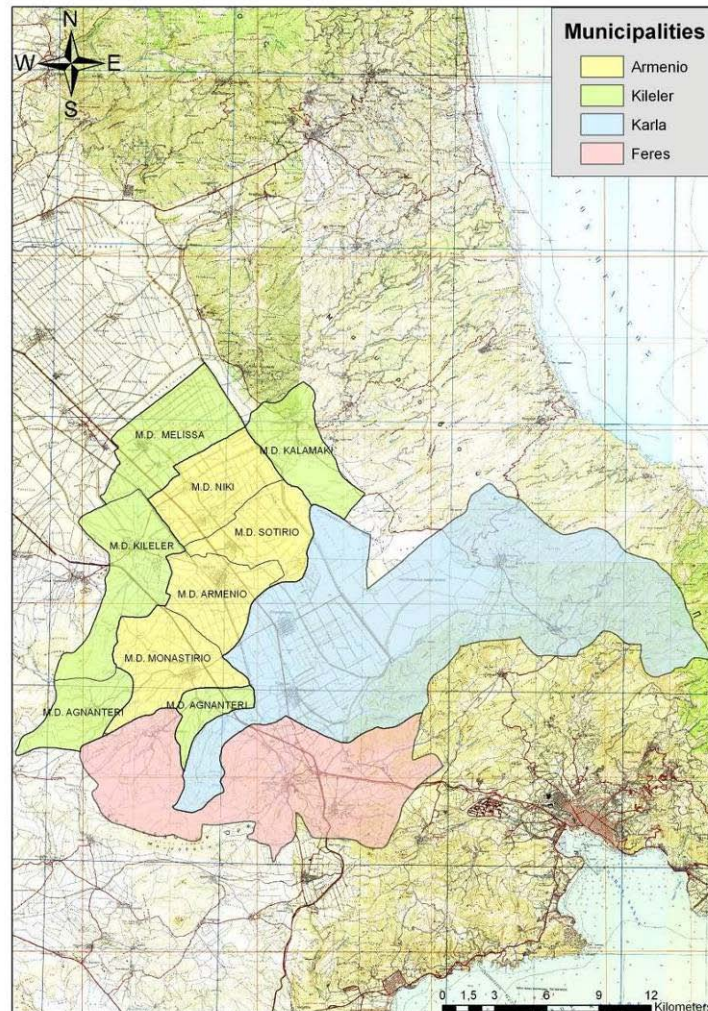


Figure 2: Municipalities and Municipality Departments of the study area.

3 METHODOLOGY

3.1 Description of the method

The estimation of the value of irrigation water and its spatial variability throughout the basin of Lake Karla, is a very important benchmark for any economic effect, which may result from multi-criteria analysis applications. For this purpose, the method “change in net-income” was selected and implemented, which is based on the indirect assessment of the irrigation’s contribution to the farmer’s income, comparing the

economic effect of two different scenarios of irrigation water supply or demand in the study area.

According to this method, the farmer's willingness to pay in a predefined increase in water quantity is considered equal to the change in farmer's income, resulting from this water increase. In several cases, the value of water is estimated by comparing the farmer's net income for two extreme farming scenarios - the current irrigated crops and the most economic efficient scheme of dry farming - in the same area and with the same climatic and soil conditions (Gibbons, 1986). The difference in their net income can be attributed entirely to the water resources consumed by irrigation. This difference constitutes the value of irrigation water as an intermediate good of agricultural production.

In practice, the method of "change in net income" is usually used to evaluate a new irrigation system to be constructed by estimating the potential added value of water to the existing farmer's income (Rodriguez et al., 2002, Said et al. 2002). In the present study, however, a reverse process was followed, due to the fully installed irrigation systems in the study area, which have been in operation for decades. Thus, the change in net income is used to estimate the value of water in a potential loss of the farmer's income due to the cessation of the current irrigation scheme and the mandatory use of dry farming (Latinopoulos and Mylopoulos, 2005).

The reason for preferring this type of analysis is because it seems more useful and more methodologically correct to assess in advance the lost value of water due to a possible future water saving policy than an ex post evaluation of the operating irrigation networks in the region (Latinopoulos and Mylopoulos, 2004).

The combined implementation of the methods of "linear programming" and the "change in net income" can provide significant results and useful conclusions (Bowen and Young, 1985). It can also eliminate some of the drawbacks and weaknesses of the implementation of each of these methods separately. For this reason, in the present study a similar combinatorial method is followed, whereby it is estimated for each reference region: a) the farmer's current net income, b) the total irrigation water consumption and c) an optimal irrigation plan of dry farming using linear programming. The difference between the two scenarios (existing irrigation and optimal irrigation plan of dry farming) defines the framework for applying the method of "change in net income" in this study.

3.2 Value of irrigation water

The value per unit volume of irrigation water ($WVAL_j$), expressed in €/m³, in a reference area j , which is located within the study area (i.e. within the basin of lake Karla), is described by the general equation:

$$WVAL_j = INPA_j / TCWR_j \quad (1)$$

where the numerator ($INPA_j$) defines the net income of the farmer's added production, while the denominator ($TCWR_j$) expresses the total irrigation water needs of all irrigated crops in the region. This equation is almost identical to the corresponding equation of Tardieu and Prefol (2002). The latter, called the above equation as the "strategic value" of water in agriculture, a value which indicates the strategic choices of the farmer to modify the production plan and adjust the irrigation needs in accordance with the overall offered irrigation water at the beginning of each growing season.

3.3 Net income of added production

We can describe the net income of the added production due to irrigation as follows:

$$INPA_t = IBPA_t - CPA_t \quad (2)$$

where $INPA_t$ is the net income from the added production during period t , $IBPA_t$ is the gross income from the added production and CPA_t is the cost of the added production. By dividing the net income from added production by the number of hectares making up the irrigated area and by the yearly supply of water, we obtain, respectively, the net income from added production per hectare and per cubic metre of water consumed in irrigation, thus:

$$IBPA_t = \sum_{i=1}^n (RR_{it} \cdot SR_{it} \cdot PR_{it} - RS_{it} \cdot SS_{it} \cdot PS_{it}) \quad (3)$$

where i is the type of the crop ($i = 1, \dots, n$), RR_{it} is the yield per hectare in irrigation farming, SR_{it} the cultivated area in irrigation farming, RS_{it} the yield per hectare in dry farming; SS_{it} the cultivated area in dry farming, PR_{it} the crop price in irrigation farming and PS_{it} the crop price in dry farming.

And thus

$$CPA_t = \sum_{i=1}^n (CR_{it} \cdot SR_{it} - CS_{it} \cdot SS_{it}) \quad (4)$$

where CPA_t is the cost of added production, CR_{it} the cost per hectare in irrigation farming and CS_{it} the cost per hectare in dry farming.

As mentioned previously, due to a possible cessation of the current irrigation scheme, farmers tend to substitute the existing crops with dry farming crops (that require minimal amounts of water). Table 1 presents the existing and their respective dry farming crops in the study area (Latinopoulos, 2006).

Table 1. Existing and their respective dry farming crops.

Existing crops	Dry farming crops	Area (ha)
Cotton	Cotton	13,793.30
Sugar beets	Lentils	356.50
Alfalfa	Vetch	154.60
Corn	Barley	536.90
Apple trees	Olive trees	415.50
Vineyards	Vineyards	5.70
Vegetables	Okra	5.70
Watermelon	Apricot	5.00
Cereals	Cereals	4,391.50
Tomatoes	Peas	126.10
Dried nuts	Dried nuts	1,060.60

3.4 Evaluation of irrigation needs

The crop water requirements were calculated using the index Net Irrigation Requirement (NIR) (USDA, 1970). For any period of time during the crop growing season, the Net Irrigation Requirement (NIR) is the amount of water which is not effectively provided by rainfall:

$$NIR = ET_c - P_{eff} \quad (5)$$

where NIR is Net Irrigation Requirement, ET_c is the crop evapotranspiration and P_{eff} the effective rainfall.

3.4.1 Evapotranspiration

Due to the limited meteorological data (temperature, precipitation) within the study area the Blaney-Criddle method was preferred in order to estimate the evapotranspiration of crops. Other methods, that might offer more accurate results, could not be implemented due to the lack of data such as wind force and direction, and according to various studies, the chosen method gives satisfactory results (Loukas et al, 2007). The calculation of the evaporation method Blaney-Criddle is based on the calculation of the reference crop evapotranspiration and the crop coefficient.

According to the Blaney-Criddle method, the reference crop evapotranspiration ET_o (mm/day) is:

$$ET_o = (0.46 * T + 8.13) * p \quad (6)$$

where T is mean daily temperature ($^{\circ}C$), p is the mean daily percentage of annual daytime hours (based on latitude) and K_c the crop coefficient.

The crop water needs ET_c (mm/day) are:

$$ET_c = (0.46 * T + 8.13) * p * K_c \quad (7)$$

where K_c is the crop coefficient (an empirical seasonal factor that provides the relationship between the requirements of the reference crop and other crops), which mainly depends on the type of crop, the growth stage of the crop and the climate.

The values for K_c derived from the Directive FAO 24 (Allen et al, 1998) and prices are set by the Greek Ministry of Agriculture based on the Directive.

3.4.2 Effective rainfall

The effective rainfall P_{eff} is the amount of precipitation after the deduction of losses from surface runoff and deep percolation below the root zone. Effective rainfall is only a portion of total rainfall P and is calculated using the following types of USDA Soil Conservation Service (USDA, 1970 & Dastane, 1974):

$$P_{eff} = \frac{P_k * (125 - 0.2 * P)}{125} \quad P < 250 \text{ mm} \quad (8)$$

$$P_{eff} = 125 + \frac{1}{10} * P \quad P > 250 \text{ mm} \quad (9)$$

3.4.3 Net Irrigation Requirement

The value of NIR is the additional water requirement of crops in mm/m² and is calculated according to the following types:

$$NIR = ET_c - P_{eff} \quad NIR = ET_c - P_{eff} > 0 \quad (10)$$

$$NIR = 0 \quad NIR = ET_c - P_{eff} < 0 \quad (11)$$

The final water requirements per month of each crop Q (m³) are:

$$Q = \frac{NIR * E}{1000} \quad (12)$$

where E (m²) is the cultivated area of the crops.

4 RESULTS

4.1 Net Income of Added Production (INPA)

The net income of the farmer's added production per municipality department of the study area, as calculated using the methodology of section 3, is presented in Table 2.

Table 2. Net income of Added Production.

Municipality	Municipality Departments	INPA (€)
Karla		5.187.951,35
Feres		1.008.998,75
Kileler	Agnanteri	326.122,50
	Kalamaki	350.669,52
	Kileler	529.346,45
	Melissa	283.277,40
Armenio	Armenio	401.317,50
	Monastirio	819.905,35
	Niki	509.789,30
	Sotirio	511.392,50

4.2 Estimation of irrigation needs

The methodology for estimating the irrigation needs of each crop was described in section 3. In this section, Table 3 presents the irrigation needs for all crops of each municipality department for an average, dry and wet rainfall season, as a result of the temperature gradient method. The final irrigation needs are multiplied by a factor of 1.49. This factor has been estimated in the paper of A. Loukas, N. Mylopoulos and L. Vasiliades (Loukas et al., 2007) for the region of Lake Karla, according to the methodology presented in section 3.

Table 3. Irrigation needs of Municipality Departments.

Municipality	Municipality Departments	Irrigation needs		
		Average year (m ³ /year)	Wet year (m ³ /year)	Dry year (m ³ /year)
Karla		26,944,654.23	2,814,716.10	21,095,083.43
Feres		5,948,588.05	7,311,748.49	4,626,681.57
Kileler	Agnanteri	3,561,570.69	4,317,992.76	2,634,193.74
	Kalamaki	7,800,110.92	9,310,895.24	6,016,106.86
	Kileler	8,969,953.67	10,740,692.82	6,739,763.00
	Melissa	5,349,202.62	6,416,508.78	4,000,151.19
Armenio	Armenio	8,122,038.07	9,784,143.44	6,042,240.29
	Monastirio	5,379,464.57	6,597,726.12	3,950,394.02
	Niki	10,398,030.52	12,501,771.24	7,741,936.45
	Sotirio	8,951,125.47	10,784,435.74	6,651,339.17

Table 4 presents the value of irrigation water WVAL (€/m³) - calculated by dividing the net profit for farmers INPA (€) with irrigation water TCWR (m³) – and the irrigation needs divided by areas of the respective regions (m³/ha).

Table 4. Irrigation water value and irrigation needs.

Municipality	Municipality Departments	Irrigation Water Value WVAL = INPA / TCWR (€/m ³)	Irrigation Needs per hectare (m ³ /ha)
Karla		0.129	6,302.30
Feres		0.114	5,675.84
Kileler	Agnanteri	0.061	6,522.54
	Kalamaki	0.030	7,335.37
	Kileler	0.040	6,885.74
	Melissa	0.036	6,786.13
Armenio	Armenio	0.033	6,634.78
	Monastirio	0.102	6,247.39
	Niki	0.033	6,740.51
	Sotirio	0.038	6,666.92

4.3 Demand curve

Based on data from Table 4 the demand curve was estimated (Figure 3). On the vertical axis is the value of irrigation water WVAL (€/m³) and on the horizontal axis, there is the irrigation water needs divided by areas of the respective regions (m³/ha).

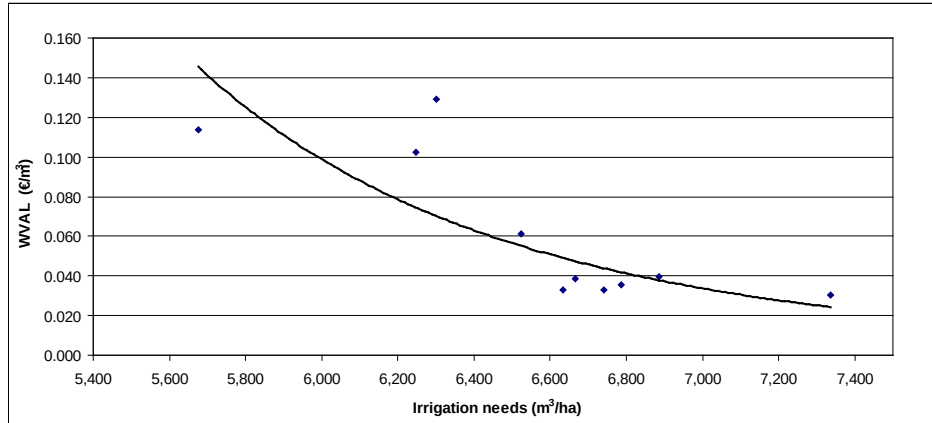


Figure 3: Irrigation water demand curve.

The aim of this paper is to assess the value of irrigation water in the Lake Karla using the demand curve, which associates the amount of water consumed by a farmer within a range of possible values. This assessment will highlight the economic contribution of water to the agricultural production, so as not to be overestimated, which may lead to increased water consumption and low economic efficiency.

By observing Figure 3 it is clear that the greater the farmer's water demand, the lower the price of irrigation water is, according to the exponential equation:

$$y = 64.644 * e^{-0.0011x} \quad (13)$$

where y is the value of irrigation water and x the irrigation water needs. It is worth noting that at the equation of the trendline the value of coefficient R^2 is 0.6946, which proves that our results are quite satisfactory.

4.4 Comparison with existing pricing policies

In Greece, in most cases, as in the case of Lake Karla basin, the consumed quantity of irrigation water is not measured, while pricing is based on irrigated area (area pricing), regardless of crop type, season and irrigation method. This pricing policy provides minimal incentives for water saving, in contrast to volumetric methods, where pricing is based on the volume of water consumed or other methods (e.g. energy consumption for pumping).

In our case, the economic value of water per hectare (€/ha) was estimated by assessing the value of irrigation water (€/m³) and irrigation water needs (m³/ha) as shown in Table 5.

The purpose of this transformation on area pricing is comparable with the current pricing policy applied by the Regional Organisation of Irrigation Networks (ROIN) of Karla. According to information from ROIN of Karla areas are irrigated by wells that exist in various areas, such as Rizomylos, Aghios Georgios and Stefanovikio. The prices for the two wells of Rizomylos are 324.00 €/ha and 509.00 €/ha, for Aghios Georgios 390.00 €/ha and for the wells located in Stefanovikio the prices are 291.40 €/ha and 623.50 €/ha.

Table 5. Economic value of irrigation water

Municipality	Municipality Departments	Economic value of irrigation water (€/ha)
Karla		814.40
Feres		646.13
Kileler	Agnanteri	400.84
	Kalamaki	221.33
	Kileler	272.72
	Melissa	241.19
Armenio	Armenio	220.02
	Monastirio	639.05
	Niki	221.79
	Sotirio	255.63

By observing the values derived from our survey and those of the existing pricing policies, we conclude that the values range at the same levels, except those of the municipality of Karla. It is worth noting that the different water price from wells of the same area (Stefanovikio) is due to various factors such as the water supply and the energy consumption of each drilling.

5 CONCLUSIONS

The present study examines the possibility of estimating the value of irrigation water as an intermediate good, the spatial variability of the value and the ability to create the demand curve that results from this differentiation. For this purpose, a typical region in Central Greece, of a large scale in order to be representative and also cover a wide basin (Lake Karla), was selected.

According to the results, there seem to be quite large variations in the value of irrigation water within the limits of a watershed, thus allowing the construction of the demand curve. The lower values appear in areas with the highest water consumption per hectare, showing the marginal cost-effectiveness of water in these areas.

The demand curve resembles the ones that derive from methods using optimization models (linear programming, multicriteria analysis, etc.). The form of the demand curve indicates however that a possible future irrigation water pricing should be around 0.04 €/m³.

A pricing policy would be particularly useful if accompanied by economic incentives to increase the efficiency of irrigation methods by promoting, for example drip irrigation. The thought behind this is that the constraint of losses would result in an increase of the value of water. Thus the farmer's income would not be additionally affected by water tariffs and all necessary resources to reinforce more efficient irrigation methods would be ensured by the ROINs.

It is worth mentioning that in the years to come the implementation of the Water Framework Directive will necessitate the estimation of the full cost of irrigation water,

including the environmental and natural resource costs. Full cost recovery will then significantly increase the burden on farmers and will affect water demand. On this account, it will be essential to estimate the irrigation water demand curve and examine the potential economic, social and environmental impacts of the different pricing scenarios, by putting particular emphasis on volumetric pricing.

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