Global NEST Journal, Vol 7, No 3, pp 323-335, 2005

VALUATION AND PRICING OF IRRIGATION WATER: AN ANALYSIS IN GREEK AGRICULTURAL AREAS

P. LATINOPOULOS

Department of Civil Engineering,
School of Engineering
Aristotle University of Thessaloniki
GR 541 24 Thessaloniki, Greece

*to whom all correspondence should be addressed
Tel:; Fax: +(30) 2310 995718
e-mail: latin@civil.auth.gr

Received: 07/06/04
Accepted: 30/08/04

ABSTRACT

Greece is a typical Southern European country in which the agricultural sector is the major consumer of water, a fact that has potential impacts on the water resources efficient allocation and management. The record-high percentage of the agricultural water use at the national level, together with a fairly loose system of water management, point out that there is a certain need for reform in related policies, including the pricing system for the provision of water services to agriculture uses. The paper presents current information and figures regarding the overall situation of irrigated agriculture in Greece and its relation to water management issues. It also illustrates a number of case studies pertinent to this sectoral water economy. A common element in all these studies is the application of appropriate methodologies that aim at valuating water for irrigation and assessing current and potential future systems of agricultural water pricing. In face of the prospect of Greece conforming to the European Water Framework Directive, the presented applications add to the ongoing debate on the applicability of the principle of full cost recovery of water services in European countries.

KEYWORDS: Irrigated agriculture, water valuation methods, water demand function, water use efficiency

1. INTRODUCTION

Water is becoming increasingly scarce in many parts of the world. Water scarcity originates from low time and space availability of the resource but, quite often, it gets to alarming levels because of intense water uses. Competition and conflicts among uses and users of water arise mostly at local and regional levels. Hence, the allocation of water among the main sector uses (i.e. domestic, industrial and agricultural) is today a critical issue for most countries in the world. Allocation is indeed a difficult task as decisions about meeting all types of water demands have to be made taking into account that various social objectives, such as economic efficiency, sustainability and equity, should be met.

In order to enable the coordination of sustainable water management activities and related policies of its member states the European Union adopted the Water Framework Directive (European Commission, 2000). The interest of the present work lies at the specific part of the Directive that refers to the cost recovery of all water services through pricing. As a matter of fact, the implementation of a pricing system that would guarantee a full cost recovery of water use seems to be a complex and debatable task, at least for some European countries. In essence, it is the efficiency of such a policy that is questionable due to specific regional or even national constraints (Tardieu and Prefol, 2002). Major obstacles to a full cost recovery are encountered in Southern European countries, in which the agricultural sector is by far the bigger water consumer. Relative experience shows that high water pricing, if not complemented by other policies, has a substantially negative impact on farmers revenues while at the same time does not safeguard sustainability, i.e. water conservation objectives (Chohin-Kuper *et al*., 2003).

In face of the inherent difficulties to conform to the European Directive, the assessment of the impacts of a potential water pricing reform in the agricultural sector in Greece was the driving force for an integrated study. This work comprised a number of case studies in typical agricultural areas in Northern Greece, which refer to both issues of irrigation water valuation and pricing.

In the next sections a brief overview of the main features of agricultural water management in Greece is first provided followed by specific case study applications, which relate to: (a) water valuation methods (namely contingent valuation and hedonic property) and (b) assessment of water pricing policies (by use of the water demand function approach and the implementation of pricing system scenarios). Overall, the paper aims at presenting the analysis of particular conditions and specific data from Greek regions and, in this way, at contributing to the ongoing debate upon the issue of full cost recovery of irrigation water.

2. THE MANAGEMENT OF IRRIGATION WATER IN GREECE

2.1 Agriculture and irrigation

As in most Mediterranean countries, agriculture is a significant sector in Greek economy. The country's governments and the EU invest in Greek agriculture in order not only to develop this particular economic sector but also to improve food security and to target populations in less favoured rural areas. Both public and private national investments in agriculture showed increasing trends during the last decade. In addition the European Union's Community Support Framework for Greece enabled the allocation of significant sums to infrastructure projects for irrigated agriculture (Mamatzakis, 2003). As a result, the contribution of the agricultural sector to Greek GNP – currently at 7% - is one of the highest in all OECD countries (OECD, 2003). The importance of the rural economy in Greece is also reflected on the fact that about 20% of the active population makes its living from agriculture. On the other hand, the Greek agricultural sector is still one of the most structurally handicapped of all OECD countries in terms of landholding structure (i.e. small farm sizes), ageing farmers and high slopes of intensively-farmed fields.

Irrigation in Greece was initially limited to few crops (e.g. horticulture and trees) but during the years it has been expanded to land cultivated, among others, by arable crops like cotton, maize and sugar beats. A strong political commitment to increase both agricultural production and farm incomes, together with private initiatives, resulted to a remarkable 65% expansion of cultivated land under irrigation in the last 25 years. This increase was more pronounced in plains than in semi-mountainous areas. Today irrigated land sums up to about 1.4 million hectares, which represent 40% of the country's total arable area and 10% of its total land surface.

The high share of the rural economy within the country's total one affects also the water resources allocation at a national basis. Thus, irrigated farming accounts for more than 80% of the nation's total water consumption, which is the highest value of this particular sectoral use of water among EU countries. Surface water accounts for around 60% of the total consumption for irrigation, while the rest is met by groundwater. At a national basis the average use of water for irrigation ranges from 5,000 to 9,000 m^3 ha^{-1} per year, depending on various factors such as type of crop, irrigation technology and local climate.

Public collective irrigation projects account for about one third of the total irrigated area, while the remaining two thirds of it are irrigated by private users. Nevertheless, public investment in irrigation has not been uniformly distributed along the country, leaving thus many regions with very few collective projects. Sprinklers dominate the irrigation technologies in Greek agriculture (public and private); yet, a recent motivation towards drip irrigation may change the current rates of technologies which are: surface 36%, sprinkler 53% and drip irrigation 11%. Public projects are more or less equipped with modern technologies (i.e. sprinkler or drip irrigation) and operate in about 60% by pressure systems, whereas in the rest 40% the less efficient gravity systems are used.

2.2. Agricultural water management

Irrigation management in Greece is a state responsibility. Public collective irrigation projects are supervised at the district (i.e. local) level by Local Land Reclamation Boards, which are typical public users organisations. General Land Reclamation Boards are responsible for the management of irrigation projects at a regional level and act as coordinating bodies of the Local Boards. On the other hand, the lack of well-structured state water authorities to supervise the irrigation activities of private users and an apparent gap in the regulation of the access to water resources has led to improper water resources management and to an inefficient use of irrigation water by this major group of farmers.

The immediate impacts from this organisational deficiency are a high decline in local water resources availability and a severe shortage in irrigation water in several important agricultural areas. In fact, in regions where collective systems are absent private users' agricultural water demand is usually met by local groundwater through a simple yet fairly uncontrolled licensing system. To start their irrigation activities farmers get rather easily a free license to abstract water; still, later on they suffer from extra costs related to borehole deepening and increased water level drawdown due to the overpumping of local aquifers by numerous abstractors.

In such a context, the lack of an efficient and equitable water pricing system is an additional handicap in the process of managing water allocation. Under the current status private users of irrigation water bear their own capital and operational costs, which, as explained above, can be high (up to a maximum of 0.25-0.40 € m^{-3}). On the other hand, users of public collective projects pay a usually low water fee (i.e. a flat rate per hectare of irrigated land) to cover the administrative as well as the maintenance and operational costs of the projects. In average this fee ranges from 120 to 500 € ha^{-1}, which is roughly equivalent to 0.02-0.08 € m^{-3}. Capital costs of irrigation water projects are covered totally by state funds, while external costs are usually not taken into account. In this way the low cost recovery of public water supply combined with the high opportunity cost of irrigation water portrays a very inefficient and non-equitable system of agricultural water provision.

From all the above it is obvious that among various practical water allocation mechanisms (i.e. marginal cost pricing, public allocation, water markets, and user-based allocation) Greece opted so far for the social planning or public type one. Apart from other drawbacks such a system usually fails to create incentives for users to conserve water and improve efficiency (Dinar *et al*., 1997). Therefore it is necessary for Greece to move as soon as possible towards a water pricing reform in the agricultural sector in order to improve water management, l*et al*one to conform to the European Directive.

3. VALUATION OF IRRIGATION WATER

3.1 Concepts and methods

The value of irrigation water is a measure of the net economic contribution of water to the value of agricultural production. As a consequence, the valuation of water used in agricultural activities is a prerequisite in the implementation of almost every pricing method. On the other hand, it is a difficult task mainly because irrigation water is a classic non-marketed resource (Dinar *et al*., 1997; Agudelo, 2000; Ward and Michelsen, 2002). Appropriate valuation techniques are based upon either observed behaviour toward some marketed good, somehow connected to the non-marketed good in question (the so-called revealed preference approach), or on stated preferences in surveys with respect to the good in question (Garrod and Willis, 1999; Agudelo, 2001).

In stated preference methods, among which the Contingent Valuation Method (CVM) is the most popular one, survey responders are offered conditions which simulate a hypothetical market, as real markets for water (i.e. the good in our case) are practically

nonexistent. Next, responders are asked to state their preferences by expressing their willingness to pay (WTP) for existing or potential conditions, including water supply and/or quality.
In brief, a good CVM survey should contain the following (Bateman and Turner, 1992; Carson, 2000): (a) an introductory section that enables the decision making to pay or not, (b) a detailed description of the good and the characteristics of its provision, (c) the institutional setting in which the good will be provided, as well as the manner in which the good will be paid for and (d) a method by which the survey elicits the responder's preferences with respect to the good, including their willingness to pay specific amounts to secure its safe provision. In the last phase of a CVM implementation proper numerical (i.e. statistics and regression) analyses of the collected data lead to an estimate of the value of the good.
Among the revealed preference approaches the Hedonic Price or Hedonic Property Method (HPM) applies to real markets for goods, which have several attributes that cannot be unbundled when purchasing and, in general, when valuing the good. So, HPM, by resting on the assumption that the price of some marketed good is functionally related to its characteristics, allows for a straightforward valuation of individual non-marketed characteristics or attributes of the good. This, so-called, implicit price of any of the good's attributes can be determined by looking at how the price people are willing to pay for the good changes when this particular attribute changes. Residential housing and land property are among the most frequently used types of such markets, in which sale price data exhibit differing but measurable characteristics, like domestic water or water for irrigation.

3.2 Application of the stated preference approach

The analyses for the estimation of the economic value of irrigation water in Greece were carried out through the application of the two major valuation approaches: (a) the stated preference approach (CVM – this section) and (b) the revealed preference approach (HPM – next section). Both case studies refer to agricultural activities in the Prefecture of Chalkidiki, a rural area in Northern Greece.
The region under study is one of the few in the country where collective irrigation networks are absent and, thus, farmers rely on their own groundwater abstraction facilities to irrigate their fields. As a consequence, there are no Local Land Reclamation Boards at all in the Prefecture and, of course, no water fees to be paid. Yet, farmers bear the often high water costs of borehole construction, maintenance and operation.
Water in the Prefecture of Chalkidiki is used to irrigate about 11,000 hectares of farmland, which is about 15% of the region's arable land that covers one third of the Prefecture's total surface. This low proportion of irrigated land is due to a seasonal water shortage resulting from the region's dry and hot climate in summer. Additional negative factors regarding the management of local water resources are the overexploitation of the local aquifers, inefficient irrigation practices and an overall lack of incentives to water conservation. The second significant water user is the domestic sector, the demand for which is very high during the summer period because of the tourist development of the coastal villages. Yet, this competitive water use is under high pressure as priority is clearly given to the irrigation sector, which accounts for 87% of the Prefecture's total water consumption.
Farm operations in Chalkidiki are almost entirely of the family-type and employ about 4,500 households involved in agricultural activities. The average local landholding structure is about 2.5 hectares per farm; a low figure that looks even worse when compared to the country's already low average of 4.1ha/farm. Shares of the total cultivated area are allocated to various crops, the major of which are olive trees, apricots, pears, corn, cotton, wheat and vegetables.
The main purpose of the CVM study that was conducted in 2000 (Mallios and Latinopoulos, 2001) is to determine the factors that influence farmers' WTP for irrigation water. The specific analysis refers to farmers attitudes towards an active participation in the set-up and operation of a water-users organisation. This future (hypothetical) scenario reflects the anticipation of irrigators for a more efficient water

provision system as well as their perception of the potential dangers from water scarcity under the current status.

Within the described framework the inclination of the farmers to participate in a user-based water allocation system is examined by utilising responses from two successive phases of the survey: (a) In the first phase, which implements a typical participation model, responders were asked if they would favour the creation and operation of such an organisation. (b) In the second phase the WTP was elicited only from positive responders to the first question. These farmers were asked if they were willing to pay a specific amount of money to confirm their participation. The model created by the answers of the second phase was next used to estimate the economic value of irrigation water.

The survey in Chalkidiki followed, as closely as possible, the standard guidelines for a good CVM application (Carson, 2000). A carefully designed questionnaire was answered through in-person interviews by a representative sample of farmers living and working in the Prefecture. In order to avoid conservative valuation estimates, payment was described not as a lump sum but as a continuing payment (i.e. a fixed annual fee), which, in any case, seems to be the most appropriate way to support an organisation like the proposed one.

Due to the binary nature of the responses in both models (i.e. ‘yes’ or ‘no’ for participation and WTP a certain amount), a logistic regression model was used to assess the factors that influence the responders behaviour as well as to estimate their WTP. In the first phase, from among 337 completed questionnaires, 218 (i.e. about 65%) expressed positive attitudes regarding participation in the organisation. Analysis of the sample’s attitudes that led to this decision showed that the main factors which dictated it were: (a) socio-economic characteristics, (b) the perception of risk towards water shortage and (c) the effectiveness of the proposed organisation.

The analysis of results from the second model indicates that farmers behaved according to economic theory, by showing a conservative attitude towards payment. Their personal attributes, like education level, and the problems they face in everyday practice are additional factors which influenced their WTP. Finally, the value of irrigation water estimated by the sample’s average WTP was €120 ha^{-1}. This is a low value as compared to similar CVM studies (e.g. Tiwari, 1998) or the HPM study carried out in the same region (Latinopoulos *et al*., 2004), which is described in the following section.

3.3 Application of the revealed preference approach

The availability of irrigation water in almost any agricultural property increases the productivity of land and, consequently, its owner’s surplus. Therefore, we can accept the hypothesis that water can be a reliable indicator of the land’s value. Within this sense, a hedonic analysis that disaggregates the agricultural land values is a reliable tool to reveal the implicit price of irrigation water. The relevant survey for Chalkidiki was designed by following standard guidelines for a successful application of HPM and was implemented by means of a questionnaire addressed to a sample of farmers who practice agriculture on owned or rented parcels of land. These farmers were asked several questions grouped to four categories of elicited data: (a) demographic and social-economic, (b) land structure, environs and location, (c) availability and methods of water supply and irrigation practice and (d) information on land values, recent transactions and prices.

The survey was conducted in the summer of 2001 and resulted in 176 completed questionnaires. In the first part of the study a statistical analysis of the sample of 176 parcels showed that the distributions of the two main variables, i.e. the parcels’ size and its value per hectare, are quite skewed: the size has a mean of 1.87ha and a median of 1.2ha, while the same statistics for the value are €49,823/ha and €26,412/ha, respectively. In the second part a hedonic price model was formulated (Latinopoulos *et al*., 2004) that is briefly described here.

Two critical decisions regarding the application of a hedonic price model relate to the identification of variables that represent the attributes of the agricultural property and the selection of the form of the hedonic price function (Garrod and Willis, 1999). In our case

the set of attributes was defined by selecting measurable variables from among the above mentioned four data categories. On the other hand, the skewed form of the distribution of land values confined our search for an appropriate functional form to a handful of logistic models. Among the most popular regression models that were tested, the semilog model performed better with the given data set and was therefore selected for the final analysis.
The regression model was evaluated using standard tests that apply in this class of econometric studies. By employing the ordinary least squares method to solve the model, the set of 6 explanatory variables (3 continuous and 3 dummy), which follow the dependent variable in Table 1, was eventually proven to be the best for our region (Latinopoulos *et al*., 2004).

Table 1. Definition and statistical summary of variables used for hedonic estimations

Variable	**Definition**	**Mean**	**SD**
LANDVAL	Natural logarithm of parcel value in €/ha (dependent)	10.141	1.019
FLDSLOP	Slope of the field: 1 if almost flat, 0 otherwise	0.582	0.494
FLDALTD	Average altitude of the field above MSL: m	166.011	178.127
OLVCULT	Olive trees in the plot: 1 if yes, 0 if no	0.631	0.484
IRRIGAT	Irrigated field: 1 if yes, 0 if no	0.659	0.475
ROADIST	Reciprocal of distance to nearest road: 1/Km	20.304	57.472
VILDIST	Reciprocal of distance to nearest village/town: 1/Km	1.667	4.073

The hedonic price function produced by the model is

$$\ln(\text{LANDVAL}) = 9.427 + 0.309\ \text{FLDSLOP} - 0.002\ \text{FLDALTD} + 0.268\ \text{OLVCULT} + 0.706\ \text{IRRIGAT} + 0.002\ \text{ROADIST} + 0.061\ \text{VILDIST} \quad (1)$$

The dominant role of the irrigation variable in the empirical model of equation 1 is more than obvious. The coefficient of this dummy variable reveals the extra value granted by the local market to irrigated properties. In fact, a reported trend of the local land market, which shows that in average prices of irrigated plots are two times the ones of non-irrigated ones, emerged in a very precise way from the estimated hedonic price function: ceteris paribus the ratio of the value of land when IRRIGAT=1 over the corresponding value when IRRIGAT=0 is equal to $e^{0.706}$=2.02.
The value of irrigated water was imputed via the land value approach in exactly the same way with previous applications of HPM (Torell *et al*., 1990; Faux and Perry, 1999). In this way, the marginal value of water for irrigation in Chalkidiki was estimated as €0.06/m^3 and corresponds to the average per area value of €407/ha that was calculated by the present model. This estimation compares well with reported values in contemporary applications of valuation techniques (Tiwari, 1998; Faux and Perry, 1999).
The main finding in both water valuation studies in Chalkidiki is that the economic value of irrigation water, either stated or revealed, lies at low levels and relates to the admittedly low water fees paid by the users of public networks in the country. This quite interesting result leads to two basic conclusions, which, not surprisingly, are not independent from to each other: (a) Farmers underestimate the true (total) value of water, as they consider only its use value and neglect important non-use value components (e.g. those related to

environmental, culture and aesthetics issues). A clear proof of this attitude is the apparent lack of any motivation to conserve water. (b) Governments are more or less aware of the situation and, as long as they favour economic development policies as opposed to sustainable environmental ones, they keep water pricing far below the full cost of irrigation water. Implications of this status are many and complex and, above all, they hinder a rational shift to more efficient and water conserving practices. Related practicalities to face the problem, including changes in the current pricing system, are discussed in the following sections.

4. PRICING OF IRRIGATION WATER

4.1 Policies and practice

In principle water pricing policies have the potential to mitigate water scarcity. As far as the agricultural water use is concerned, it is argued that water pricing can play a significant role in making this use more efficient, while at the same time reducing pressures on the environment and freeing water resources for other competing uses. Overall, in strict economic terms water pricing is the main mechanism for cost recovery. Yet, the effectiveness of the financial and economic roles of water pricing policies depends on the pricing method, the individual sector to be charged and, of course, the country in question.

The body of the literature pertaining to irrigation water pricing is vast and diverse. A number of major reviews accumulate recent knowledge on the implementation and performance of existing pricing methods (Johansson, 2000; Roth, 2001; Bosworth *et al*., 2002; Johansson *et al*., 2002; OECD, 2002). An important observation is that in many countries the prevailing factor in the decision making process regarding irrigation water pricing is politics. For example, there are places where the provision of irrigation water is viewed as a human rights issue and therefore pricing water at high rates is considered politically unacceptable. Of major concern for some national water policies is also the fact that water use in agriculture has to be subsidised. In summary, irrigation water pricing policies vary remarkably among countries. Still, policies targeted at full cost recovery are not widespread.

The most popular pricing method of irrigation water is area pricing, according to which farmers are charged a fixed price per unit of irrigated land. It is a method easy to implement with low water administration costs. It does not require metering of water provision and is best suited to continuous flow irrigation. However, area pricing is based on the assumption that irrigated land surface is an adequate proxy for the volume of water received, which is not actually true. Furthermore, area pricing has little effect on water use equity and efficiency, as charges are not a direct function of water consumption and the marginal cost of irrigation water is zero. Hence, the method is used by water boards to conveniently recover their costs and not to provide users with incentives to reduce water consumption.

On the other hand, the most favoured pricing mechanism among economists and environmentalists is the volumetric method, by which water is charged according to directly measured volumes of consumed water. In volumetric pricing the price of a unit of water may be assigned to its marginal cost, giving thus the right economic incentives to farmers to limit their irrigation up to a socially optimal level of consumption. Despite its theoretical superiority, implementation of volumetric pricing is not always feasible as it requires: (a) information on the volume used by each individual farmer and (b) a central water authority to set prices, monitor use and collect fees. In most cases it is difficult and expensive to enforce installment of measurement devices and to monitor legal and/or illegal abstractions. If agriculture income is low water costs may outweigh the revenues of many farmers, a fact that hinders equity. Tiered pricing may compromise this problem, as payment rates change only when the amount of water consumed exceeds certain pre-imposed threshold values. Finally, two-part tariff pricing (i.e. charging a constant marginal price per unit of water and a fixed annual charge), betterment levy pricing (i.e. water fees per area, based on the incremental land value due to irrigation) and water markets (i.e.

trade of water rights among farmers) are alternative but not frequently used methods of irrigation water pricing.

4.2 Application of the demand function approach

The case studies that are presented in this and the following section refer to the pricing system in Greek areas in which irrigated agriculture is served by public collective projects. The water demand function approach, which is highlighted in this section, is employed to evaluate various impacts (i.e. economic, social and environmental) of the implementation of any pricing policy that is targeted at full water cost recovery. In the next section two alternative pricing scenarios are proposed in order to achieve a more equitable and efficient water allocation, without significantly burden the income of farmers.

The study area for the following applications is the southern part of the Basin of Loudias River. It is located in Northern Greece, 30 km west of the city of Thessaloniki, spanning over an area of about 700 Km^2. More than 82% of this area is cultivated (i.e. a total of 58,000 ha of farmland) of which only 3% under dry conditions. Irrigation needs are met mostly by surface water through pressure or gravity systems, while in a small part of cultivated land private users are being served by local groundwater. The region is known for its very productive agriculture, the main crops being cotton, rice, corn, sugar beats and fruit trees. All these crops are high water-consuming, resulting thus in intensive irrigation with an annual average consumption of about 7,000 m^3 ha^{-1}.

The extensive network of collective irrigation projects that operate in this region is administered centrally by a General Land Reclamation Board based in Thessaloniki and locally by 21 Local Boards. Area pricing is the sole mechanism for partial water cost recovery (i.e. administration and supply costs). Per hectare prices are not uniform among regions that are under the control of different Local Boards, as every one sets a uniform flat rate according to its financial needs, with the exception of rice cultivation. In fact, rates for rice (150-280 € ha^{-1}) are quite higher than those set for the rest of crops (70-175 € ha^{-1}).

The water demand function methodology was applied to the study area in two separate studies: (a) One in the area of concern of one Local Land Reclamation Board that covers 5,000 hectares (Latinopoulos *et al*., 2003) and (b) a subsequent one covering the total area of the 21 Boards (58,000ha) (Latinopoulos *et al*., 2005). As results from the two studies showed no significant differences due to scale the following presentation refers to the second study only.

The derivation of the irrigation water demand function for the study area is accomplished by following a standard methodology based on a linear programming (LP) model (Amir and Fisher, 1999; Berbel and Gomez-Limon, 2000). With this approach a single objective, i.e. the maximisation of farmer's profit, is met for a series of water pricing policies. In this way, as the price of the unit of water supply increases, and so does the overall water cost, farmers tend to look for less water-demanding crops or even non-irrigated ones.

The decision variables, X_i, of the LP model are the areas of the cultivated crops, plus an extra variable, SA, which refers to set-aside (a subsidised activity). With this model the decision-maker (i.e. the farmer) can decide upon the level of use of water by modifying the type, number and distribution of his crops. Formulated in this way, each resulting crop plan is characterised by the differing values of some important attributes: (a) the gross margin, which is used herein as a reliable estimator of profit, (b) the water consumption, which is controlled via changes in the water management policy, and (c) the employment, which is computed as the sum of labor time for all farming activities.

Gross margin (GM) is assigned a direction of improvement, as we look for its maximisation, and it is therefore selected as the objective function of the LP model. All pertinent data are given in Table 2 and relate to the year 2002. Note that in Table 2 the 'zero price' policy is only illustrated, which means that gross margin data shown in the table do not include volumetric water pricing costs, but only the standard per hectare fee that is already included in the variable costs. All other alternative policies exhibit reductions in the values of the gross margin each irrigated crop, which are equal to the product of the water unit price times the water demand estimates.

Table 2. Data for the LP model

Crop	Variable	Irrigation Method	Gross Margin (€ ha^{-1})	Water Demand (m^3 ha^{-1})	Labour needs (hours ha^{-1})
Cotton	X1	Sprinkler	749	5,691	290
Rice	X2	Surface	1,027	11,977	170
Corn	X3	Sprinkler	397	6,344	290
Peach trees	X4	Surface	2,128	7,558	680
Sugar beats	X5	Sprinkler	874	7,461	330
Alfalfa	X6	Surface	995	9,089	250
Other trees	X7	Surface	6,296	7,461	920
Tomatoes	X8	Sprinkler	2,368	5,597	380
Vegetables	X9	Sprinkler	5,600	8,114	1,030
Hard wheat	X10	Non-irrigated	362	0	40
Tobacco	X11	Surface	5,035	5,853	1,290
Asparagus	X12	Sprinkler	1,364	8,114	1,000
Tobacco	X13	Non-irrigated	490	0	1,280
Cotton	X14	Non-irrigated	252	0	130
Set-aside	SA	-	220	0	0

The LP model is solved for each unit water price level by maximising the gross margin function

$$GM = \sum GM_i \cdot X_i \qquad (2)$$

under a set of constraints related to land, Common Agriculture Policy (CAP) requirements, and market or agronomic restrictions (Latinopoulos *et al*., 2005). The principal output of this optimisation process is the water demand curve shown in Figure 1. From this figure it appears that this is a classic demand curve that reflects the adaptation of farmers to rising costs of production inputs.

As seen in Figure 1, the demand curve can be divided into four segments, i.e. two inelastic followed by two elastic ones. These variations are related to significant changes in the crop plan and to the main attributes: water consumption, farm income and agricultural employment.

The analysis of the variation of these attributes, which depend strongly on increasing unit water prices, shows that: (a) For low water prices there is no substantial saving of water due to the inelastic form of the demand curve. (b) When price increases the crop plan changes remarkably resulting to water saving. Yet, the loss in the revenues of farmers and the reduction in the demand for labour are significant and create serious socio-economic problems to the agricultural sector.

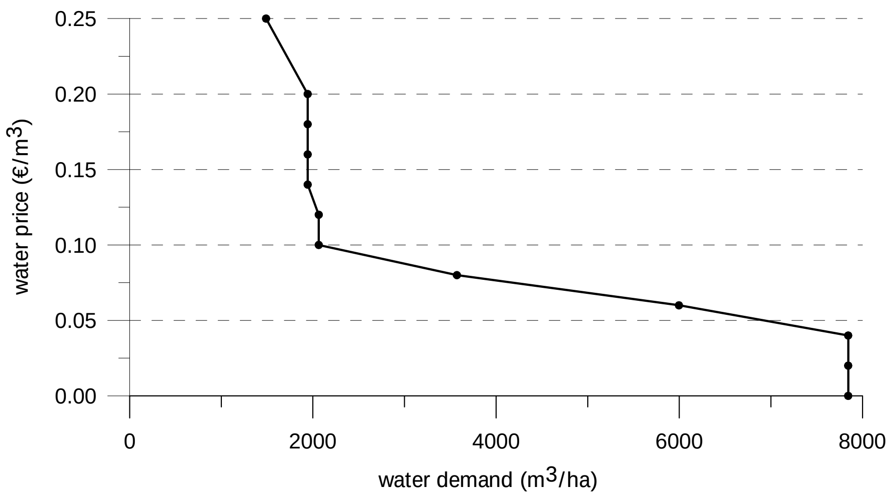

Figure 1. The irrigation water demand function for the study area (Loudias River Basin)

A more effective solution to the problem seems to be a combination of water pricing at low unit rates (just to make farmers respect the valuable water resources) and the implementation of a quota system in the provision of irrigation water. Figure 2 shows the results from the application of such a combined system. Here it can be clearly seen that water saving can be achieved in a more natural and effective way and, above all, with no dramatic reductions in the income of farmers, only when water price remains below the threshold value of 0.04€ m^{-3}.

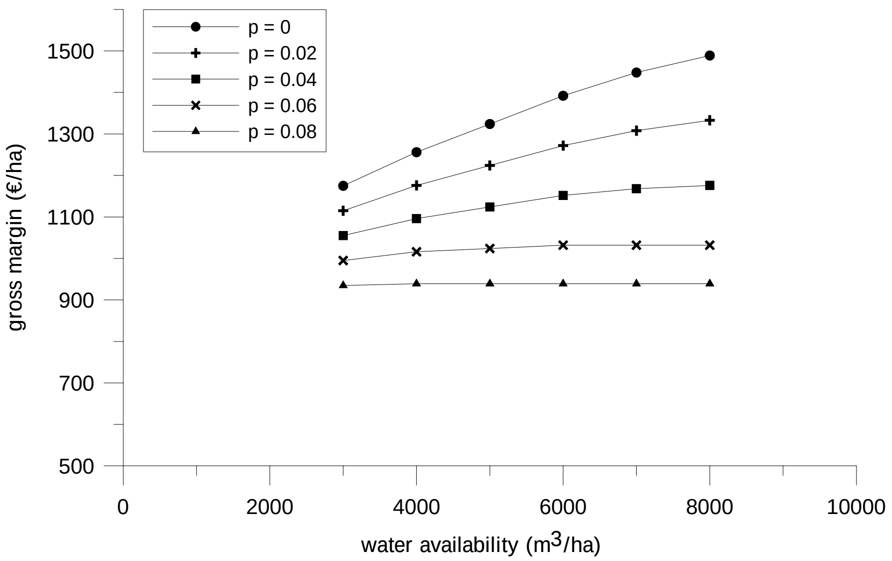

Figure 2. Variation of gross margin in relation to the availability of water for various price levels

4.3 Application of alternative policy scenarios

The current, financially-oriented, area pricing system in the Basin of Loudias River results in significant regional variations of water charges, which fluctuate from 95 to 170 € ha^{-1} (i.e. the average values of the 21 Local Land Reclamation Boards). The question posed is whether these differences reflect an analogy in the levels of actual water consumption or not. To check this local average water consumption per hectare was estimated for each one of the 21 districts and the result was compared to their average area pricing values. As shown in Figure 3, and more accurately through a correlation analysis of these two variables, it is evident that charges are not correlated with consumption (R=0.41) and are therefore unable to provide water use efficiency.

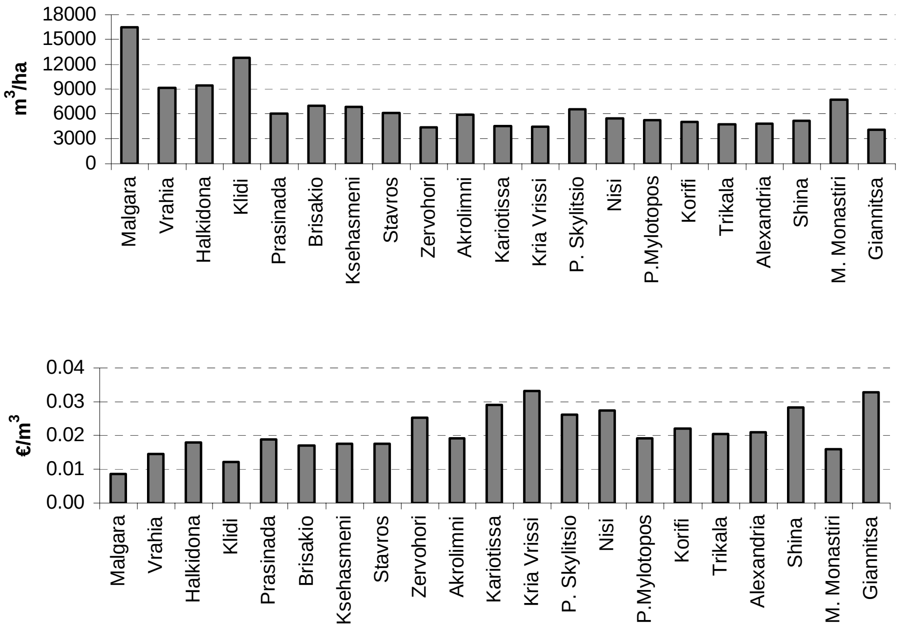

Figure 3. Variations of water consumption and water price per unit of actual water consumption in the 21 irrigation districts of Loudias Basin

Apart from water use efficiency, irrigation water prices should also ensure equity. This means improving either the allocation of the resource (i.e. how the resource is distributed to users) or the allocation of the benefits of the resource (i.e. how the benefits are distributed to users) (Bosworth *et al*., 2002). Following the second interpretation, one should look at reforming the water pricing policy in order to reduce the resultant differences in farm income among the irrigation districts. Pointing at this direction, a water pricing reform in the area under study was examined (Latinopoulos and Mylopoulos, 2004).

As an intermediate step before the implementation of a volumetric method, which, as explained above, is very problematic in most agricultural areas, a second best pricing policy was chosen to overcome the deficiencies of the existing one. The proposed modification associates the water pricing system to crop selection. This method does not encourage water savings for a given choice of crop, but it certainly can discourage cultivation of certain water-consuming crops, if higher pricing rates were applied to them. Within this sense two alternative pricing scenarios were put under consideration.

With the first scenario, which complies with the Water Framework Directive, the General Land Reclamation Board bears the total costs of the Local Boards that should not exceed their current figures. The proposed pricing system intends to come as close as possible to the volumetric one by apportioning the overall consumption of irrigation water according to crop requirements and then by charging each crop's water use in a weighted per district basis. The second scenario aims at satisfying the concepts of the first one (i.e. a uniform per area pricing system providing equity to all irrigators), while imposing the constraint that all Local Boards should cover on their own the current budgets in their districts. In this context the aim is to estimate the minimum total revenue that arises from an area pricing system subject to the above constraints as well as to water charge constraints. Water charges would be higher than those resulting from the previous scenario in order to provide water use efficiency, but less than the currently paid charges, in order to ensure social acceptance. A specific LP model was formed to solve this second problem (Latinopoulos and Mylopoulos, 2004).

In brief, the results from the two problems are as follows. First of all, in both cases average pricing have to be increased in order to tackle the current quite uneven distribution of costs among users. Thus, the calculated prices under the first scenario vary, according to crop selection, from 105 to 201€ ha^{-1}. However, efficiency in pricing is now much more secure as compared to the existing system, as the values of per area water consumption and regional water charges of all districts are highly correlated (R=0.83). Under the second scenario, water prices vary in the 21 irrigation districts from 115 to 250 € ha^{-1}. It should be noted that, under this scenario, total water revenues increase significantly (20.4%) in order to ensure current district revenues. The correlation between water prices and consumption (R=0.70) is not as high as under the first scenario but, still it is much higher than the one under the current pricing system.

As far as equity is concerned, it was shown that the most equitable scenario, irrespective of water consumption, is the first one, while the second scenario seems to be better than the current situation only under specific conditions (Latinopoulos and Mylopoulos, 2004). As a final remark, it should be underlined that an improved cross-district water allocation without decreasing total water supplies would certainly result in higher equity.

5. CONCLUSIONS

As shown in the paper, the role of irrigation in Greece, as in all Southern European and, in general, Mediterranean countries, is an essential element of agricultural production. The intensity of irrigation in the region is high due to several factors like climatic conditions, types of cultivated crops and applied farming methods.

In the paper appropriate methodologies were applied for the valuation of water for irrigation and the assessment of the impacts of existing and potential systems of water pricing in typical Greek agricultural areas. These applications revealed some interesting findings which can be summarised in the following set of conclusions.

(a) The value of irrigation water, as estimated either directly or indirectly by water users, is low because it relates to its use component. Environmental and resource issues are not given any particular concern and this is probably the major reason of the significant absence of water conservation attitudes.

(b) The target of improving agricultural productivity puts a great pressure on water resources. However, it seems quite difficult to change the current status in which agriculture is one of the most favoured sectors in Greece’s economy.

(c) Nevertheless, a reform in the pricing system for irrigation water is quite essential in order not only to conform to the relevant principles of the European Water Framework Directive but also to mitigate the negative impacts of the existing system, including the lack of efficiency and equity.

(d) On the other hand, the results of the case studies show that the application of the principle of full cost recovery produces negative social impacts. Moreover, it is not an efficient water management tool when implemented on its own.

(e) As a general rule, one can propose that properly designed water management policies that aim at environmental and economic goals should also take into account the social impacts to the main stakeholders, i.e. the farmers. Within this sense, the provision of water services can be best implemented by combining a water pricing structure that ensures equity at low price levels with a more strict and efficient administrative system that will safeguard the sustainability of water resources.

REFERENCES

Agudelo, J.I. (2001), The Economic Valuation of Water - Principles and Methods, Value of Water Research Report Series No. 5, IHE Delft.

Amir, I. and Fisher, F.M. (1999), Analyzing agricultural demand for water with an optimizing model, Agricultural Systems, **61**, 45-56.

Bateman, I.J. and Turner, R.K. (1992), Evaluation of the Environment - The Contingent Valuation Method, CSERGE Working Paper GEC 92-18.

Berbel J. and Gomez-Limon J.A. (2000), The impact of water-pricing policy in Spain: an analysis of three irrigated areas, Agricultural Water Management, **43**, 219-238.

Bosworth, B., Cornish, G., Perry, C. and van Steenbergen, F. (2002), Water Charging in Irrigated Agriculture – Lessons from the Literature, HR Wallingford, Report OD 145.

Carson, R.T. (2000), Contingent valuation: a user's guide, Environmental Science and Technology, **34**, 1413-1418.

Chonin-Kuper, A., Rieu, T. and Montginoul, M. (2003), Water policy reforms: pricing water, cost recovery, water demand and impact on agriculture - Lessons from the Mediterranean experience, Water Pricing Seminar, Agencia Catalunia delAgua and World Bank Institute, Barcelona.

Dinar, A., Rosegrant, M.W. and Meinzen-Dick, R. (1997), Water Allocation Mechanisms – Principles and Examples, The World Bank, Washington, D.C.

European Commission (2000), Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for community action in the field of water policy, Official Journal of the European Communities, L327, 22/12/2000.

Faux, J. and Perry, G.M. (1999), Estimating irrigation water value using hedonic price analysis: a case study in Malheur County, Oregon, Land Economics, **75**, 440-452.

Garrod, G. and Willis, K.G. (1999), Economic Valuation of the Environment, Edward Elgar.

Johansson R.C. (2000), Pricing Irrigation Water - A Literature Review, Report No. WPS 2449, The World Bank, Washington, D.C.

Johansson R.C., Tsur Y., Roe T.L., Doukkali R. and Dinar A. (2002), Pricing irrigation water: a review of theory and practice, Water Policy, **4,** 173-199.

Latinopoulos D. and Mylopoulos Y. (2004), Efficiency and equity considerations on irrigation water pricing: a case study in Loudias river basin, Proc. Inter. Confer. "Protection and Restoration of the Environment VII", Mykonos (accepted for publication).

Latinopoulos, D., Latinopoulos, P. and Mylopoulos, Y. (2005), The variation of irrigation water demand as a consequence of its pricing, Proc. 5th National Conference of the Hellenic Commission for the Management of Water Resources "Integrated Management of Water Resources on a Watershed Basis", Xanthi (in Greek - accepted for publication).

Latinopoulos, P., Antonopoulou, E. and Tziakas, V. (2003), Derivation of the irrigation water demand function: a Greek experience, Proc. 8th Inter. Confer. "Environmental Science and Technology", Lemnos Island, Vol. A, 539-546.

Latinopoulos, P., Tziakas, V. and Mallios, Z. (2004), Valuation of irrigation water by the hedonic price method: a case study in Chalkidiki, Greece, Water, Air & Soil Pollution: Focus (in press).

Mallios, Z. and Latinopoulos, P. (2001), Willingness to pay for irrigation water: a case study in Chalkidiki, Greece, Proc. 7th Inter. Confer. "Environmental Science and Technology", Ermoupolis, 566-573.

Mamatzakis, E.C. (2003), Public infrastructure and productivity growth in Greek agriculture, Agricultural Economics, **29**, 169-180.

OECD (2002), Transition to Full-Cost Pricing of Irrigation Water for Agriculture in OECD Countries, OECD, Paris.

OECD (2003), OECD in Figures – Statistics on the Member Countries, OECD Observer.

Roth, E. (2001), Water Pricing in the EU – A Review, European Environmental Bureau, Publication No. 2001/002.

Tardieu, H. and Prefol, B. (2002), Full cost or "sustainability cost" pricing in irrigated agriculture. Charging for water can be effective, but is it efficient?, Irrigation and Drainage, **51**, 97-107.

Tiwari, D.N. (1998), Determining Economic Value of Irrigation Water, CSERGE Working Paper GEC 98-05.

Torell, A., Libbin, J. and Miller, M. (1990), The market value of water in the Ogallala aquifer, Land Economics, **66**, 163-175.

Ward F.A. and Michelsen, A. (2002), The economic value of water in agriculture: concepts and policy applications, Water Policy, 4, 423-446.