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Conflicting Implementation of Agricultural and Water Policies in Irrigated Areas in the EU

José A. Gómez-Limón[1], Manuel Arriaza and Julio Berbel

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Irrigated agriculture is directly influenced by various EU policies, especially the CAP and more recently the Water Framework Directive (WFD). The demand for water by agriculture is largely determined by CAP policy. On the other hand, the objective of the WFD is to regulate the supply (cost, quality, quantity) of water to agriculture. This work examines the relationships between these two policy instruments and applies a scenario analysis to a case study in central Spain using a multi-criteria model of farmer behaviour. The results show that the two instruments must be co-ordinated in order to meet socio-economic goals (farmers' income and labour demand) and environmental protection (water-use efficiency).

1. Objectives and Background

Irrigated agriculture is very important in terms of area, value of production and employment in Mediterranean regions devoted to continental agriculture. This paper analyses the impact of CAP reform and the Water Framework Directive (WFD) in irrigated agriculture through a case study in Central Spain. We believe that this research will contribute to our understanding of the complexities linking agricultural and environmental policies in irrigated agriculture. We begin by introducing CAP policy and the Water Framework Directive.

Agenda 2000 and the future of the CAP

The history of the CAP has always been one of adaptation to internal and external forces on the agricultural sector. There has been a continuous series of modifications to policy goals and instruments in reaction to the changing agricultural environment. The latest significant changes were adopted in 1999 as part of the Agenda 2000 framework, which aims to solve internal (justification of social support) and external (the next WTO round and EU enlargement) problems (Buckwell, 1997). They continue the momentum of the 1992 Reforms in that farmers are compensated by direct payments for successive reductions in institutional prices in an attempt to decouple production from

[1] José Gómez-Limón is at the Department of Agricultural Economics, E.T.S.II.AA. University of Valladolid Avda. Madrid, 57. 34071 Palencia. SPAIN. E-mail: **limon@iaf.uva.es** for correspondence. Manuel Arriaza is at the Department of Agricultural Economics, CIFA Alameda del Obispo. P.O. Box 3092. 14080 Cordoba, SPAIN. E-mail: **economia1.cifao@cap.junta-andalucia.es** for correspondence. Julio Berbel is at the Department of Agricultural Economics, E.T.S.I.A.M. University of Cordoba. Menéndez Pidal s/n. 14071 Cordoba, SPAIN. E-mail: **berbel@uco.es** for correspondence. Thanks are due to the two reviewers for comments on an earlier draft of this paper.

financial support. Some experts, however, have criticised this reform as being too timid since it fails to provide an adequate solution to these problems.

In this new scenario, agricultural sectors with higher productivity will be more greatly affected than low-input agriculture, and irrigated agriculture will be severely jeopardised because:

i) Irrigation is highly intensive in energy, chemicals and labour, and its products may not be competitive under international competition and price conditions.
ii) The supply of "environmental goods" is more difficult to justify in irrigated agriculture as opposed to extensive low-input agriculture.

The Water Framework Directive and EU environmental policy

As pointed out above, irrigated agriculture is influenced by both agricultural and environmental policy, mainly via water management regulations. Given that water use by Spanish agriculture accounts for 80 per cent of total consumption, the growing demand from urban and industrial sectors has led to severe criticism of the inefficiencies of water distribution and its use by farmers. Public debate about water use was inflamed by the latest severe drought (1991-95) and by the Government's recently proposed Hydrological Plan. Some authors argue that Spanish irrigated lands are being mis-managed on the grounds of excessive water losses in distribution channels and during application to the soil. Moreover, some claim the use of water to produce large amounts of low value-added, heavily subsidised crops is itself untenable.

In consequence, according to these critics, irrigation is efficient neither in technical nor economic terms, and there is no need to increase the supply of water to agriculture. On the contrary, they claim that more emphasis should be put on demand-side policies and on solutions such as water pricing, water markets and the modernisation of irrigation systems (Randall, 1981).

Overlaying this debate is the view held by some local authorities who advocate the "social" distribution of water on the basis of "social value" as opposed to traditional water rights linked to ownership of the land.

In 1995 the European Commission and Parliament initiated the process of developing a Common Policy on Water, as part of Article 130R of the Treaty of the Union that empowers Brussels to protect the environment. Many issues have formed barriers to an early agreement, but one of the most difficult has probably been Article 9 in the initial drafts of the proposal, which originally obliged EU members to charge the full cost of water to users. The final agreement is much more vague, establishing that EU members should try to recover all water service costs, including environmental costs, in accordance with the "polluter pays" principle.[2]

The classical microeconomic view of water pricing (Spulber and Sabbaghi, 1994, Tsur and Dinar, 1995, Hall, 1996) fails to recognise the social impact of irrigation, i.e. its contribution to rural development and employment in less favoured areas. On environmental grounds, irrigation also helps to maintain population levels in sensitive areas and thus helps to slow down the progress of desertification in arid regions. Some of these experiences can be found in OECD (1999), and research on Spanish cases can be found in Varela-Ortega *et al.* (1998), Berbel and Gómez-Limón (2000) and Feijoó *et al.* (2000). These authors all argue that price increases force farmers to change cropping patterns in the direction of less water-intensive crops, some of them heavily subsidised by the CAP, as opposed to labour-intensive irrigated crops. They also conclude that rigidities in supply should be taken into consideration, finding that responses to price increases may only produce significant water savings when price is already severely affecting farmers' incomes.

Research objective

The analysis of the effects of water pricing on irrigated agriculture and farmers' behaviour should be an important topic of research for European agricultural and environmental economists, and this study attempts to establish a methodology that will enable us to study the inter-relationships between both of these common policies and their influence on agricultural irrigation systems. This methodology, based on Multi-Criteria Decision-Making Theory, will be implemented in a real irrigation system, enabling us to build a model that enables us to:

i) Analyse how the recent CAP reform has influenced the water demand function and how hypothetical new reforms would affect the irrigation unit studied.
ii) Measure the impact of the hypothetical total costs proposed by the WFD.

The various effects of the WFD and CAP on irrigated areas can be found in Berbel and Gómez-Limón (2000) and Gomez-Limon and Berbel (2000), which deal with the former policy, and Gómez-Limón and Arriaza (2000), on the

2 It is also worth mentioning that two other domestic policies related to irrigation water have been recently approved in Spain. Those are the creation of water markets (Water Act, 1999) and the modernisation of irrigation systems (National Irrigation Plan, 2001). Both measures, which are being implemented in order to improve water efficiency, are due to be complemented by concrete administrative rules. Nevertheless, this paper will focus only on the two European policies indicated above.

latter one, based on the same area. The conclusions that can be drawn from these studies lead us to hypothesise that there is a contradiction between these two policies: on the one hand, the CAP favours free trade and the competitiveness of EU agriculture, while on the other, the WFD tries to impose additional costs on irrigated farming, negatively affecting its competitiveness. The methodology adopted here, which analyses various CAP and WFD scenarios, confirms this hypothesis.

2. Multi-criteria Methodology for Agricultural Decision Modelling

In contrast to the classical approach, we assume that not only does profit determine the level of the farmer's utility, but that risk (the second moment of the profit) is also important. For expositions of Multi-criteria Decision-Making techniques in agriculture see Anderson *et al*. (1977), Hazell and Norton (1986), Romero and Rehman (1989) and Hardaker *et al*. (1997).

Multi-Attribute Utility Theory (MAUT) is one approach to the Multi-Criteria Decision-Making paradigm. It is often argued that MAUT has the soundest theoretical structure of all multi-criteria techniques (Ballestero and Romero, 1998). At the same time, from a practical point of view, the elicitation of utility functions presents many difficulties. In this paper, we follow a methodology that attempts to overcome these limitations.

Both the additive and multiplicative forms (Keeney, 1974) of the multi-attribute utility functions have been elicited on the grounds of expected utility theory through techniques that involve the decision-maker's choice between a certain outcome and a lottery (Anderson *et al.*, 1977, Biswas, 1997, Hardaker *et al.*, 1997). The additive utility function has been widely used to model farmers' decisions when one of the criteria involved is uncertainty. The ranking of alternatives is obtained by adding contributions from each attribute. Since attributes are measured in terms of different units, normalisation is required to permit addition. The weighting of each attribute expresses its relative importance.

Fishburn (1982) presents the mathematical requirements for assuming an additive function. Although these conditions are somewhat restrictive, Edwards (1977) and Farmer (1987) have shown that the additive function yields extremely close approximations to the hypothetical true function even when these conditions are not satisfied. In Hwang and Yoon's words (1981, p. 103): “theory, simulation computations, and experience all suggest that the additive method yields extremely close approximations to very much more complicated non-linear forms, while remaining far easier to use and understand”.

In what follows, once the use of the additive utility function has been justified, we take a further step in assuming that the individual attribute utility functions are linear. Hence, the mathematical expression takes its simplest form:

$$U_i = \sum_{j=1}^{n} w_j r_{ij} , \qquad i = 1, ..., m \tag{1}$$

where U_i is the utility value of alternative i, w_j is the weight of attribute j and r_{ij} is the value of attribute j for alternative i.

Although the assumption of linearity of the individual attribute utility function is rather strong, and may even be unrealistic, the validation of the model supports this decision. Since we aim to rank alternatives as the decision-maker would do, the mathematical form of the utility function is less important. We claim that the utility functions presented in this paper are a good approximation to the farmers' hypothetical utility functions. Furthermore, the use of the E-V linear approximation gives a local measure of risk aversion (see for example Huirne and Hardaker, 1998).

The utility function: method of elicitation
Once we agree to use additive and separable utility functions, the ability to simulate real decision-makers' preferences is based on the estimation of relative weightings. We have selected a methodology in which the utility function is elicited on the basis of the revealed preferences implicit in the actual values of decision variables (i.e. the crop plan in farm management). The methodology was developed by Sumpsi *et al.* (1997) and extended by Amador *et al.* (1998). It is based upon weighted goal programming and has previously been used by Berbel and Rodríguez (1998), Gómez-Limón and Berbel (2000) and Gómez-Limón and Arriaza (2000).

The method may be summarised as follows:

1. Each attribute is defined as a mathematical function of decision variables (f_i), x (e.g. crop area); $f_i = f_i(x)$. These attributes are proposed *a priori* as the most relevant decision criteria utilised by farmers (usually profit, risk, etc.).
2. The pay-off matrix is calculated, where f_{ij} is the value of the i-th objective when the j-th objective is optimised. The main diagonal is the “ideal” point defined by the individually obtained optimum.
3. The following $q+1$ system of equations is solved

$$\sum_{j=1}^{q} w_j f_{ij} = f_i \;\; i = 1, 2, ..., q \;\; \text{and} \;\; \sum_{j=1}^{q} w_j = 1 \tag{2}$$

   where q is the number of *a priori* relevant objectives, w_i are the weights attached to each objective (the solution), f_{ij} are the elements of the pay-off matrix and f_i the real values reached in the observed behaviour of farmers, as obtained by direct observation.

4. Normally, there is not an exact solution to system (2) and it is therefore necessary to solve a problem by minimising the sum of deviational variables that find the closest set of weights

$$\text{Min} \sum_{i=1}^{q} \frac{n_i + p_i}{f_i} \text{ subject to:}$$

$$\sum_{j=1}^{q} w_j f_{ij} + n_i - p_i = f_i \quad i = 1, 2, ..., q \text{ and } \sum_{j=1}^{q} w_j = 1 \qquad (3)$$

where n_i and p_i are, respectively, negative and positive deviations.

Dyer (1977) demonstrates that the weights obtained in (3) are consistent with the following separable and additive utility function.

$$U = \sum_{i=1}^{q} \frac{w_i}{k_i} f_i(x) \qquad (4)$$

where k_i is a normalising factor (i.e. the difference between maximum and minimum values for objective 'j' in the pay-off matrix).

The proposed method provided a utility function that can be used as an instrument capable of reproducing the observed behaviour of the farmer.

3. Scenario Analysis

The primary aim of the multi-criteria methodology is to define the objective function (multi-attribute utility function) developed in order to simulate the behaviour of farmers in the area under study. However, we wish to build a model capable of simulating the farmers' probable responses to WFD and CAP changes. The first step, therefore, is to define the likely scenarios for both policies, which we do below.

WFD scenarios

We have commented above that the WFD requires member states to introduce water prices that integrate the "polluter pays principle" (PPP); thus, increasing the price compels the user to make more rational use of water. The first practical problem that we encounter is the lack of information regarding the cost of irrigation water that should be used by each member state to implement the WFD. The somewhat limited number of studies that address this issue are summarised below:

i) Naredo and Gascó (1994) estimate the average cost of water supply to agriculture in Spain to be around 18 ptas/m^3 (0.108 €/m^3). This figure is obtained from the total value of infrastructure investment and other hydraulic services and by dividing this value among areas of consumption (urban and irrigation). The weakness of this work is that it does not place any value on environmental and risk protection uses.

ii) Escartín and Santafé (1999) study a number of Spanish catchments, including the River Duero Valley. The results for this watershed conclude that the average cost of irrigation water is 6.77 ptas/m^3 (0.041 €/m^3).

iii) Segura (1997) estimated average water costs in more than 80 Spanish irrigation reservoir systems (depreciation and cost of distribution). The results for the area under study (Bajo Carrión), served by the Camporedondo and Compuerto dams, estimated reservoir depreciation costs at 1.7 and 1.6 ptas/m^3 respectively. The cost of distribution along the channels to the irrigated area is approximately 1 pta/m^3. Total costs are thus below 3 ptas/m^3 (0.018 €/m^3).

As we can see, the cost range depends on the level of analysis, and in practice it is difficult to establish a reliable cost estimate for irrigation. We have therefore selected three scenarios for water price in this study.

i) *"Low" price*. This considers a price of 4 ptas/m^3 (0.025 €/m^3). This price will not, in our opinion, be capable of recovering total costs, but it might at least serve as a financial instrument to encourage efficient resource use.

ii) *"Medium" price*. A price of 6 ptas/m^3 (0.036 €/m^3) may be regarded as a fair value for cost recovery.

iii) *"Hard" price*. A price of 8 ptas/m^3 (0.048 €/m^3) would be a tough application of PPP, including a provision for environmental costs.

CAP scenarios

In accordance with the literature reviewed we have selected five scenarios for the evolution of the CAP (named A to E) and a recent situation (Pre-A) that can be used as a reference for comparative analysis. The scenarios are described below:

i) *Scenario Pre-A*. This is the norm of the recent past, valid until 1998-99, that embodies the 1992 Reform, with a support price for cereals of 119.19 €/t and direct deficiency payments for cereals= 54.34 €/t, oilseeds= 94.24 €/t, pulses= 78.49 €/t and set-aside= 68.83 €/t. Set-aside was fixed at 5 per cent in the last season.

ii) *Scenario A*. This is the current Agenda 2000 scenario, following the 1999 reform, which is to be fully applied after the 2002 season. This reform is based upon lower support prices for cereals (-15 per cent) and direct deficiency payments that will rise to partially compensate for the loss of income. These are fixed at 63 €/t for all products including set-aside, which is fixed at 10 per cent of the annual crop area. Pulses receive a premium of 9.5 €/t. As is well known, payment is linked to a subsidy based upon 'theoretical' yields of land, and is distributed regionally at county level. In Spain, after the experience of the 1992 reform, a new distribution of yields (and thus of direct payments) has increased average Spanish productivity from 2.0 t/ha to 2.64 t/ha, and therefore real and theoretical productivity have been approximated. Furthermore, an internal domestic distribution scheme has been modified in order to allow for increases in the theoretical productivity of irrigated land. The consequences for the area under study have been:

Average yield 1997 = 3.1 t/ha ⇒ Average yield. 2000 = 3.6 t/ha
Maize yield 1997 = 6.5 t/ha ⇒ Maize yield. 2000 = 7.5 t/ha
Rest of cereals yield 1997 = 3.0 t/ha ⇒ Rest of cereals yield 2000 = 3.5 t/ha

iii) *Scenario B*. Direct payments reduced by 50 per cent. This hypothesis is based on future forces on a medium-term horizon as a response to the CAP environment, in particular WTO negotiation rounds and EU enlargement. The other parameters (e.g. support price) remain unchanged.

iv) *Scenario C*. This scenario intensifies the free-trade measures advanced in the previous hypothesis. In this case the modest support price that was established by Agenda 2000 remains as the only protection instrument, while the rest of the support (direct payments) disappears. In this scenario theoretical yield estimations and set-aside are irrelevant.

v) *Scenario D*. The hypothesis here is that liberalisation measures implemented in response to internal and external forces will force the EU to decrease its support price, but with no modification of direct payments to compensate for loss of income as determined by Agenda 2000. This hypothesis is similar to Scenario A, but prices are reduced by 30 per cent, in an attempt to proxy world market prices.

vi) *Scenario E*. The initial Agenda 2000 proposal suggested the establishment of a single productivity estimator for all crops (including maize and set-aside). The agreement finally reached was the same as in Scenario A, but we wish to study the effect of the original proposal, which suggested a common theoretical yield of 5.6 t/ha, (a weighted average of the actual proposal). The remaining parameters remain as in Scenario A.

Table 1 summarises the parameters that define each scenario.

Table 1: CAP Scenarios

	Scenario Pre-A (Before Agenda 2000)	Scenario A (Agenda 2000)	Scenario B (Direct payments decrease)	Scenario C (Direct payments suppressed)	Scenario D (Prices decrease)	Scenario E (Unified theoretical yield)
Crop price variation	Current	-15%	-15%	-15%	-30%	-15%
Direct payments* (€/t)	Cer. = 54.34 Oils. = 94.24 Pul. = 78.49 SA = 68.83	Cer. = 63.0 Oils. = 63.0 Pul. = 72.5 SA = 63.0	Cer. = 31.5 Oils. = 31.5 Pul. = 36.3 SA = 31.5	Cer. = 0 Oils. = 0 Pul. = 0 SA = 0	Cer. = 63.0 Oils. = 63.0 Pul. = 72.5 SA = 63.0	Cer. = 63.0 Oils. = 63.0 Pul. = 72.5 SA = 63.0
Theoretical yields (t/ha)	Average = 3.1 Maize = 6.5 Other cer.= 3.0	Average = 3.6 Maize = 7.5 Other cer = 3.5	Average = 3.6 Maize = 7.5 Other cer.= 3.5	Average = -- Maize = -- Other cer. = --	Average = 3.6 Maize = 7.5 Other cer.= 3.5	Average = 5.6
Set-aside	5%	10%	10%	0%	10%	10%

*Cer. = Cereals; Oils. = Oilseed; Pul. = Pulses and SA = Set-aside.

Finally, it would be useful to note the following:

i) We assume that a 15 per cent (30 per cent for Scenario D) reduction in support price is transferred directly to the market and thus to farmers. Crop gross margins are reduced accordingly in the model.

ii) As Agenda 2000 has proposed equal direct payments for cereals and oil seeds, the Blair House Agreement regarding maximum oil seeds area is not applicable (this is common to all scenarios except Pre-A).

iii) There is no provision for modulation of subsidies either according to farm size or eco-conditionality.

iv) Fixed farming costs are regarded as constant during the period of study. This assumption seems reasonable because we are modelling a short time period, without dynamic adaptation. Hence, the water price is the only input price that changes in the simulation.

4. Description of the Case Study

The range of types of agriculture practised in a Mediterranean country such as Spain is enormous, particularly when irrigation is permitted. Coastal plains devoted to orchards (citrus fruits, etc.), protected horticulture (tomatoes, peppers, etc.) or open-field extensive temperate crops (cotton, rice, etc.) and the higher altitude inland plateaux devoted to continental crops (winter cereals, sugar beet, etc.) all characterise Spanish agriculture. Each of these agricultural systems requires detailed individual analysis because problems, solutions and impacts will be quite different for each of them. We have selected for study the area called "Comunidad de Regantes del Bajo Carrión", located in the province of Palencia in North-Central Spain.

Gómez-Limón and Berbel (2000) have described this area, which can be briefly summarised as a relatively modern irrigated area created by the Government in the 1970s, with 6,600 hectares worked by 907 farmers (average area 7.42 ha). It is self-regulated via a co-operative irrigation association known as the "Comunidad de Regantes" (CR). Irrigation is mainly through inundation, and sprinklers are used for sugar beet only. This area has common climate, soil type and water availability and farms are similar both in terms of size and cropping patterns[3].

The climate may be defined as continental, with long cold winters and short hot summers. As rain falls mainly in the autumn and winter, water is a limiting factor in the warm and hot summer season, and irrigation is required to raise productivity.

A typical cropping pattern in a "normal" year (i.e. without water restrictions) in the area under study is as follows: winter cereals (29 per cent), maize (28 per cent), sugar beet (14 per cent), alfalfa (9 per cent), sunflower (5 per cent) and other minor crops.

The water required for irrigation is approximately 4,500 m^3/ha, which is sufficient for this cropping pattern, but in dry years the water supply is considerably lower. The water tariff in the irrigated area consists of two components, whose 1998 values were:

Comunidad de Regantes Tariff...................2,000 ptas/ha (12.02 €/ha)
Duero River Authority Tariff....................4,300 ptas/ha (25.85 €/ha)

The first is the "internal" Irrigation Unit distribution cost including administration and control, while the second is supposed to cover abstraction, storage and transport from reservoir to the Irrigation Unit (to the main distribution channels owned by the Authority).

The average cost of water is thus about 1.0 ptas/m^3 (0.006 €/m^3) for a "normal" hydrological year, which is well below the costs estimated by the studies quoted

[3] As Gómez-Limón and Berbel (2000, p.53) point out: "We selected this region because it is relatively homogeneous". In a similar study on water demand curves (Arriaza *et al.*, 2002), we have undertaken a different type approach in an area of Southern Spain where the differences among farms (in terms of both farm size and crop distribution) were justified to group farmers into three categories.

above, but the payment by farmers resembles a licence fee related to farm area rather than to water abstraction and use.

We selected this area because it is a good representative of North and Central Spain and is fairly homogeneous both in physical terms (soil and climate) and in socio-economic conditions. Since we are relying on the rather strong assumption of a common utility function for all farmers in the community, only their similarities in both crop distribution and farm size allow us to justify such a simplification.

Furthermore, since this is a relatively new CR, it possesses high-quality data. Our information is therefore based on the CR's own figures, and on those of the local government and the river authority. Direct questioning and interviews with 50 farmers enabled us to compile the information required to build the models.

5. Multicriteria Model

We define a mathematical model as a system conceptualised via a mathematical simplification of relevant variables and their inter-relationships. Every system has variables that determine the processes involved. Those that belong to the decision-making process are "decision variables"; e.g. the farmer himself can determine his crop distribution and his level of water consumption. The crop plan selected will also determine the "attributes" of the system. Attributes are functions that are deduced from the decision variables, but not all attributes are relevant to the decision-makers. Fertiliser consumption, for example, may be an attribute of interest to policy-makers but irrelevant for producers. Attributes to which decision-makers assign a desired direction of improvement are considered "objective functions". In this study we analyse not only the farmers' own objectives but also attributes that are relevant to policy-makers, as we explain in the following section.

Variables

Each farmer member of the "Comunidad de Regantes" has a set of variables X_i (crops), as described in the previous section. These are the decision variables that may assume any value belonging to the feasible set.

Objectives

Three objectives must be regarded as belonging to the farmer's decision-making process:

- i) *Profit maximisation, estimated as the expected total gross margin (GM).*
- ii) *Risk minimisation, measured as the variance of total gross margin (VAR).*
- iii) *Minimisation of labour inputs, in terms of hours of labour required.*

The first two objectives are classical in agricultural economics: a large number of works quote their importance in farm decision-making. The third has been included as a consequence of our field research and it is regarded as *a priori* relevant by experts and farmers. This hypothesis will therefore be tested by the weighted goal programming algorithm.

Constraints

i) *Land constraint.* The sum of all crops must be equal to 100: we thus obtain the results in percentages and do not allow land to lie idle.

ii) *CAP constraints*. We have assumed 5 per cent set-aside for COPs. Sunflower is limited to 50 per cent of the farm area. Sugar beet, because of the quota, is limited to the maximum hectarage in the period.

iii) *Rotational constraints*. Alfalfa is the sole non-annual crop, remaining in the ground for four years, after which it cannot be sown for three years. The maximum area covered by alfalfa may be calculated as:

$$X_{alfalfa} \leq m/(m+n) = 4/(4+3) \cdot 100 = 57.14$$

where "m" represents the number of years of the crop on the land and "n" the number of years before repeating on the same plot.

iv) *Market constraints*. Alfalfa is the only perishable crop in the list considered. We decided to limit its hectarage to the maximum in the period 1993-97.

A detailed description of a similar model can be found in Gómez-Limón and Berbel (2000), where a functional expression of each equation used is shown.

Multicriteria model results

a) Payoff matrix:

From the model described above we have obtained the individual optima. These are shown in the payoff matrix below, in which each column is the result of individually maximising/ minimising three objectives (max. gross margin, min. variance and min. labour)

Table 2: Payoff matrix for a 100 ha farm

	Objective to be optimised			Observed Value
Value obtained	GM	VAR	Labour	
GM (10^3 pesetas)	14,128	3,414	2,776	12,329
VAR (10^8 pesetas^2)	39,454	558	863	21,283
Labour (hours)	810	94	40	706

b) Objective weights:
By solving the system of equations (3) above, we obtain the following weightings, which minimise deviations from present real values.

W_1 (max GM)	=	0.832
W_2 (min VAR)	=	0.168
W_3 (min Labour)	=	0.000

From these weights we may deduce that farmers in an irrigation unit at the aggregate level behave according to an additive utility function, in which the objectives considered are the maximisation of Gross Margin (GM) with a weight of 0.8321 and the minimisation of risk (measured as variance) with a weight of 0.1679. Therefore, revealed behaviour at the aggregate level may be represented by a utility function as follows:

$$U = 83.21\%\ MB - 16.79\%\ VAR \qquad (5)$$

Following equation (4) we must normalise to allow for addition. In order to obtain this adimensional function a preferred factor is obtained, in which each objective is divided by the range between "ideal" or best value and worst value in the pay-off matrix. GM is divided by (14,127,856 - 2,776,139) and VAR by (39,454 - 558), giving the standardised utility function:

$$U = 7.33 \cdot 10^{-8}\ GM - 431.69 \cdot 10^{-8}\ VAR \qquad (6)$$

Being essentially the same, the following expression will be used as a surrogate utility function

$$U = 7.33\ GM - 431.69\ VAR \qquad (7)$$

Model validation
We proceed to validate the model, by comparing real values with predicted behaviour (Qureshi *et al.*, 1999). Model parameters should relate to the Pre-A Scenario that was valid for the 1998/99 season, with a water price of zero. Table 3 summarises the validation:

Table 3: Validation (100 ha)

Objectives	Observed value	Predicted values*	Deviation (%)
Gross Margin (10^3 pesetas)	12,329	13,567	9.13
Variance (10^8 pesetas^2)	21,283	25,362	-16.08
Labour (hours)	706	796	11.22
Decision variables (ha)	Observed crop mix	Predicted crop mix*	Deviation (%)
Winter Cereals	33.10	29.94	3.16
Maize	31.94	34.44	-2.50
Sugar Beet	15.97	20.50	-4.53
Sunflower	6.25	0.00	6.25
Alfalfa	10.53	11.91	-1.38
Set-aside	2.20	3.22	-1.02
TOTAL	100.00	100.00	18.84

* Values for Pre-A scenario with water price equal to zero.

Water demand functions

Once we are convinced that the models are a good representation of real decision-making, we estimate water demand functions. This is done for each CAP scenario in order to estimate the farmers' willingness to pay for irrigation water in each of the price/subsidy environments. This is done in order to acquire sufficient knowledge to enable us to study the various water pricing alternatives.

We need to derive six different demand curves, a process that requires adaptation of the original models:

i) The objective function is always the above-mentioned expression (7).
ii) The gross margin in each case includes an extra cost defined by water demand and price paid.
iii) We include new alternative crops in order to allow for non-irrigated and partially irrigated crops.

The last consideration implies that as the price of water increases, we must permit the use of crops with little or no irrigation. For each irrigation level we have estimated gross margin and technical coefficients, and each dose is a new activity.

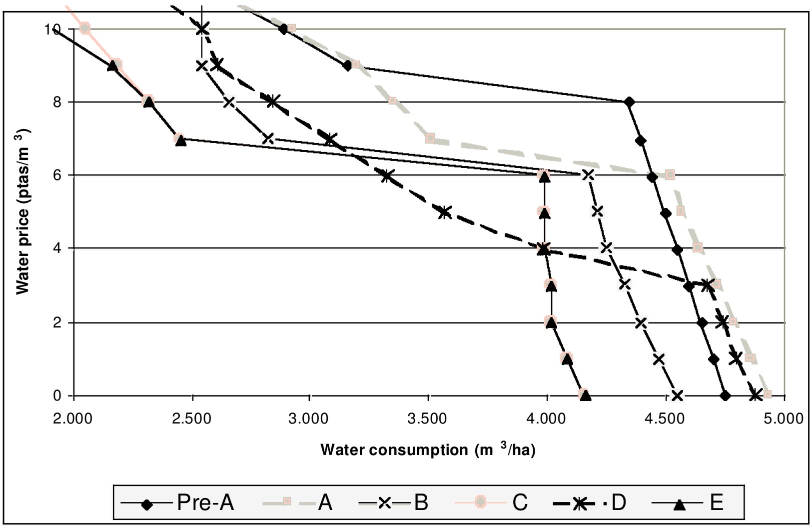
In order to estimate the demand curve we run the model using different water prices, starting with zero until we reach the point of no water demand. Thus, for each policy scenario we calculate an optimum crop plan that enables us to measure the relevant variables for the policy makers (system attributes): namely, water consumption, agricultural income, farm labour and fertiliser use.

6. Results

Water demand functions

Water consumption can be analysed through the water demand curve. The results of the six CAP scenario simulations are shown in Figure 1 below for a series of water prices. As we would expect, the demand curves exhibit a negative slope.

Figure 1: Water Demand Functions



The figure shows that there are large differences in demand, according to the CAP scenario modelled; this is rational, since the farmer's willingness to pay depends upon the economic profitability of water as a production factor. Nevertheless the functions follow a similar pattern:

i) Inelastic segment. At low water prices, demand does not decrease because the farmer does not change his crop area: water payments do not achieve their objective, as water consumption is not reduced.

ii) Elastic segment. Once a certain threshold has been passed, demand behaves with an elastic response to price rises, by substituting water-intensive crops with others that demand less water.

This behaviour has been described in several previous studies, e.g. Wahl (1989), Montginoul and Rieu (1996), Varela-Ortega *et al.* (1998) and Gómez-Limón and Berbel (2000).

This is a very important conclusion if we intend to adopt water pricing as an instrument for environmental policy because significant savings are only achieved when prices are within the "elastic" segment. When we look for an explanation of the slow response to water price in the first segment, this is due, in our opinion, to the narrow range of crops that a particular farmer is capable of cultivating in a given area: when water price rises, the only possible adaptation to rising factor cost is the substitution of irrigated crops by non-irrigated crops for all CAP scenarios. Looking at the boundary between the two segments of the demand curve, we see that it is characterised by the replacement of irrigated wheat by non-irrigated barley, which happens when the utility function for both crops is similar. From this point on, a sequential substitution of irrigated crops takes place in the following order: wheat, maize, alfalfa and sugar beet are replaced by barley and sunflower, which are the only crops above 20 ptas/m^3 (0.120 €/m^3).

The threshold defined by the point at which the utility of irrigated wheat is equal to that of rain-fed barley is highly dependent on the CAP scenario, as is summarised in Table 4, where we can see that the inelastic segment is shorter. The threshold is currently (Pre-A scenario) located at 8 ptas/m^3, but moves downwards to 6 ptas/m^3 for scenarios A, B, C and E (price reduction of around 15 per cent) and sinks to 3 ptas/m^3 for scenario D (prices reduced by 30 per cent).

Table 4: Segments in water demand functions

	Inelastic (ptas/m^3)	Elastic (ptas/m^3)
Scenario Pre-A	0-8	> 9
Scenario A	0-6	> 7
Scenario B	0-6	> 7
Scenario C	0-6	> 7
Scenario D	0-3	> 4
Scenario E	0-6	> 7

Another difference is the demand function itself, i.e. volume as a function of price. We can see how demand moves leftwards as subsidies or direct payments decrease (scenarios A, Pre-A, B and C respectively). This behaviour is a consequence of the decreasing utility obtained by maize in these scenarios, since maize is less profitable (currently, Agenda 2000 gives this crop a higher subsidy than other cereals) and is simultaneously more risky (as income from maize is more variable than that from winter cereals). The combination of decreasing relative profitability and increasing relative higher variability makes maize less competitive in the utility function. Since maize is the crop with the highest water requirements, this phenomenon is capable of explaining most of the reduction in demand.

Table 5 below shows the combined effects on water demand of CAP scenarios and water price increases.

Table 5: Water demand scenarios *

	Tariff = 4 ptas/m^3	Tariff = 6 ptas/m^3	Tariff = 8 ptas/m^3
Scenario Pre-A	-4.3%	-6.5%	-8.7%
Scenario A	-2.3%	-4.8%	-29.5%
Scenario B	-10.6%	-12.3%	-44.0%
Scenario C	-16.1%	-16.1%	-51.2%
Scenario D	-16.2%	-30.0%	-40.1%
Scenario E	-16.1%	-16.1%	-51.2%

* Percentages computed on basis of 1999 level (Pre-A and water price= 0): water use= 4,751 m^3/ha.

We can summarise the reduction in water demand as a function of:

i) *Water price*: it is obvious that a rise in price will decrease demand, but it is important to know the form of the function, particularly when the demand is inelastic, as higher prices will have only a small effect on water demand but a significant impact on farmers' income. Results suggest that the threshold will be between 3 and 8 ptas (0.019 and 0.049 €) depending on which agricultural policy is implemented.

ii) *Cereal support price*: the decreasing price support lowers the threshold, i.e. demand becomes elastic at lower prices (see Scenario D).

iii) *Direct subsidies*: lower direct payments modify the relative utility of maize (the most water-intensive crop) moving the curve leftwards (see scenarios A, B and C).

We can conclude that an agricultural policy based upon price reduction will have a greater impact on water demand than a direct reduction in subsidies.

If we analyse the current CAP scenario (A), the results show that water price must be above 6 ptas/m^3 (on the elastic segment) to produce a significant reduction in demand for water. In order to achieve a 30 per cent reduction in the 1998/99 demand we would have to set a price of 8 ptas/m^3, while the previous CAP scenario only achieves an 8 per cent reduction at a price of 8 ptas/m^3.

An interesting scenario is ‘E', in which, since the direct payment to farmers is made the same for all crops at an average level, the relative profitability of maize is considerably reduced against that of winter cereals, which use less water. Consequently, demand for water decreases significantly, with a 50 per cent reduction at 8 ptas/m^3.

Economic impacts: farm income and public revenue
The attribute associated with farm income is gross margin, and simultaneous modifications of CAP and WFD will produce the impacts summarised in Table 6.

Table 6: Economic impact *

	Tariff = 4 ptas/m^3		Tariff = 6 ptas/m^3		Tariff = 8 ptas/m^3	
	GM decrease (%)	Public revenue (ptas/ha)	GM decrease (%)	Public revenue (ptas/ha)	GM decrease (%)	Public revenue (ptas/ha)
Scenario Pre-A	-13.7%	18,179	-20.2%	26,650	-26.3%	34,707
Scenario A	-15.8%	18,559	-22.5%	27,141	-28.3%	26,814
Scenario B	-32.4%	16,999	-38.2%	25,012	-42.5%	21,290
Scenario C	-49.7%	15,945	-55.1%	23,918	-58.9%	18,535
Scenario D	-27.6%	15,926	-33.0%	19,966	-37.0%	22,771
Scenario E	-13.0%	15,945	-18.4%	23,918	-22.2%	18,535

* Percentages computed on basis of 1999 level (Pre-A and water price=0): GM=147,794 ptas/ha and Public revenue=0.

Generally speaking, this simulation shows that water pricing involves some loss of income. This is partially due to transfers to the water authorities through water pricing, although most losses are a result of crop substitution. This can be seen in detail in terms of:

i) *Expenses directly due to water price*. This implies that income is transferred by farmers to the water authorities, to recover the full cost of water infrastructure as proposed by the WFD.
ii) *Substitution of more profitable crops*. An arid climate such as we find in the Duero Valley is characterised by water as the limiting factor, because the climate would otherwise permit the cultivation of more profitable crops. This is the case for maize, alfalfa and sugar beet.

This economic impact is reinforced when the reforms of the CAP are implemented. It is obvious that any reform of the CAP in the present situation will decrease farm income because of the highly protected state of European agriculture. In this case, any decrease in agricultural protection will be transferred either to public-sector savings (less direct subsidies) or to consumer savings (lower prices).

Table 6 shows that the combined effects of CAP reforms and WFD water pricing would have an enormous impact on farm income. Therefore we may compare the pre-A situation with the other scenarios; some of them show a loss of income of around 50 per cent of pre-A levels. We can also see how, at low levels of water price, i.e. within the inelastic part of curve, most of the income lost is directly transferred to the public revenues, but as the price rises above threshold and reaches the elastic segment there comes a point at which public-sector revenue begins to decrease and savings are transferred to other users.

Nevertheless, water pricing is an efficient instrument when the resource saved can be put to alternative uses (private, environmental) but if other such uses do not justify the savings, the loss of farm income will result in a global loss for the whole economy. Greater losses of income are obviously found in scenarios with lower direct subsidies and higher water prices (scenario C, water price= 8 ptas/m^3).

Scenario A deserves to be paid particular attention because it is the one currently in force. Our analysis suggests:

i) Losses are due mainly to water pricing as the CAP reforms involve only minor modifications of the Pre-A situation.
ii) When water pricing passes 6 ptas/m^3, public revenue decreases. Above this level, recovery of the cost of water may not be possible.

We should also pay special attention to scenario E because this is the strategy that simultaneously saves the greatest amount of water and causes the least loss to farmers' income. This is because maize is the greatest consumer of water and its area decreases in this scenario, since direct subsidies are similar for all cereals. This is generally the case for this scenario but is particularly true when the price of water is above the 6 ptas/m^3 threshold.

Social Impact: farm labour

As water price increases and demand decreases, the demand for labour also falls, because of the fact that water-intensive crops demand more labour per unit area than crops with lesser water needs. Table 7 summarises the social effect on each of the scenarios described here:

Table 7: Employment and Nitrogen Use*

	Tariff = 4 ptas/m^3		Tariff = 6 ptas/m^3		Tariff = 8 ptas/m^3	
	Employment (%)	Nitrogen (%)	Employment (%)	Nitrogen (%)	Employment (%)	Nitrogen (%)
Scenario Pre-A	-0.7%	-5.0%	-1.0%	-7.6%	-1.3%	-10.1%
Scenario A	-0.4%	-0.3%	-0.8%	-3.4%	-1.2%	-11.2%
Scenario B	-1.6%	-12.5%	-1.9%	-15.1%	-2.3%	-23.7%
Scenario C	-2.4%	-21.1%	-2.4%	-21.1%	-3.6%	-31.9%
Scenario D	-0.5%	-2.5%	-1.3%	-11.7%	-2.0%	-20.4%
Scenario E	-2.4%	-21.1%	-2.4%	-21.1%	-3.6%	-31.9%

*Computed on basis of 1999 level (scenario Pre-A and water price= 0): Employment= 7.85 hours/ha and Nitrogen= 223.44 N.Units/ha.

When we compare losses in employment with income losses, we can see that there are differences, because even in the most favourable scenarios (C and E with water price= 8 ptas/m^3) this remains below 4 per cent. This fact may be explained by studying crop plans, where we can see that the most intensive crops (sugar beet and alfalfa) are cultivated in the crop plan until the price of water reaches 15-20 ptas/m^3, (well over the highest pricing value). The impact would probably be greater if the Common Market Organisation (CMO) of these crops were reformed.

We may thus conclude that the impact on employment is due only to the substitution of maize and wheat by non-irrigated barley. This change would primarily affect water consumption and farm income while derived employment would be only slightly affected. Finally, this conclusion is related only to farm employment as such, and we are careful to limit our conclusions to the rural level since the policy impact on suppliers and agribusiness in general is more difficult to estimate.

Environmental impact: fertiliser use

Table 7 also shows the impact of water pricing on fertiliser use, as intensive agricultural production implies higher fertiliser use, especially of nitrates. Obviously, in arid conditions water is a constraint and the use of fertiliser should be reduced in order to avoid soil and plant stress. There is a close correlation between water consumption and fertiliser use, and in the inelastic segment there is thus no significant reduction in nitrogen use because crop plans (and water consumption) are quite stable.

The evolution of fertiliser use depends more heavily on CAP policy since maize is highly dependent on fertiliser (needing three times as much nitrogen as winter cereals). When we study the evolution of crop plans, we can see how fertiliser consumption correlates with maize cultivation). In consequence, scenarios C, D and E show a steeper fall in fertiliser use as maize profitability is modified by the new CAP subsidies policy.

7. Concluding Remarks

This study illustrates the links between environmental policy and agricultural policy, focusing on the possible evolution of CAP policy and WFD instruments. The results confirm our initial hypothesis about the possible conflicting implementation of both policies in European irrigated areas. Thus, while the future CAP will probably favour free trade and will encourage the competitiveness of EU agriculture, WFD implementation will impose additional costs on irrigated farming, negatively affecting its competitiveness.

Our findings suggest the need for a close co-ordination between both policies in order to avoid major problems in irrigated areas (particularly the abandonment of farms). We believe that our research demonstrates that environmental goals (e.g. efficiency of water use) targeted via economic instruments (water pricing) can achieve the desired results without excessive negative impacts on farm income.

We suggest that the only way to co-ordinate these policies is through the development of a greater understanding of irrigated agricultural systems. The methodology we propose may thus be useful for simulations of farmers' behaviour when more than one objective is included.

Results from this study demonstrate that:

- i) The impact of water pricing on water demand depends upon the functional form of the demand curve. In this study we have identified two distinct segments of the curve illustrating that farmers willingness to pay for water is determined by CAP instruments.
- ii) Due to the small number of competitive crops in this ecosystem, the first segment of the curve (low-medium level of water prices) implies that farmers will reduce their income (gross margin) by 15-25 per cent before water use starts to decrease. If this is combined with CAP liberalisation, income may be reduced to 50 per cent of present levels, which would have a socially and environmentally catastrophic impact (desertification of rural areas).
- iii) Since Duero Valley agriculture is highly mechanised, the effects on direct farm employment will not be significant unless water pricing is excessive (over 15 ptas/m^3). Nevertheless, indirect employment effects and the decline in economic activity in rural areas may be an important consideration that has been ignored in this analysis.

Overall, the combined effect of both policies on fertiliser use is significant, as both penalise nitrogen-intensive crops. Nevertheless, our opinion is that fertiliser use is a parameter that must be taken into consideration not only in quantitative terms (as is the case in this research) but also qualitatively (i.e. its influence on cultivation techniques) in order to measure the real impact on diffuse pollution.

Finally, it should be noted that our conclusions would be quite different in coastal and temperate irrigated areas, where the farmer's willingness to pay for water is significantly higher and crops are mainly competitive non-subsidised horticulture. Further research should therefore be undertaken in the field of scenario analysis applied to other relevant agricultural systems.

References

Amador, F., Sumpsi, J.M. and Romero, C. (1998). A Non-interactive Methodology to Assess Farmers' Utility Functions, An Application to Large Farms in Andalusia, Spain. *European Review of Agricultural Economics*, **25 (1)**, 95-109.

Anderson, J.R., Dillon, J.L. and Hardaker, J.B. (1977). *Agricultural Decision Analysis*. Iowa: Iowa University Press.

Arriaza, M. and Gómez-Limón, J.A. (2000). *Local Water Markets For Irrigation in Southern Spain, A Multicriteria Approach*. XXIV International Conference of Agricultural Economics. International Association of Agricultural Economics (IAAE). Berlin (Germany).

Arriaza, M., Gómez-Limón, J.A. and Upton, M. (2002). Local Markets for Irrigation Water in Southern Spain: a Multicriteria Approach. *Australian Journal of Agricultural and Resource Economics* 46 (1), 1-23.

Ballestero, E. and Romero, C. (1998). *Multiple Criteria Decision-Making and its Applications to Economic Problems*. Amsterdam: Kluwer Academic Publishers.

Berbel, J. and Gómez-Limón, J.A. (2000). The Impact of Water-Pricing Policy in Spain, An Analysis of Three Irrigated Areas. *Agricultural Water Management*, **43 (2)**, 219-238.

Berbel, J. and Rodríguez, A. (1998). An MCDM Approach to Production Analysis, An Application to Irrigated Farms in Southern Spain. *European Journal of Operational Research*, **107 (1)**, 108-118.

Biswas, T. (1997). *Decision-Making under Uncertainty*. London: MacMillan Press.

Buckwell, A. (1997). *Towards a Common Agricultural and Rural Policy for Europe*. Brussels: European Economy, Reports and Studies nº 5. European Commission.

Dyer, J.S. (1977). *On the Relationship Between Goal Programming and Multiattribute Utility Theory*. Discussion paper 69, Management Study Center. University of California, Los Angeles.

Edwards, W. (1977). Use of Multiattribute Utility Measurement for Social Decision-Making. In Bell, D.E., Keeney, R.L. and Raiffa, H. (eds.), *Conflicting Objectives in Decisions*. Chichester: John Wiley and Sons.

Escartín, C.M. and Santafé, J.M. (1999). Application of the Cost Recovery Principle in Spain, Policies and Impacts. In European Comission DGXI and Instituto da Água (eds.), *Pricing Water, Economics, Enviroment and Society*. Sintra.

Farmer, P.C. (1987). Testing the Robustness of Multiattribute Utility Theory in an Applied Setting. *Decision Sciences*, **18 (2)**, 178-193.

Feijoó, M., Calvo, E. and Albiac, J. (2000). Economic and Environmental Policy Analysis of the Flumen-Los Monegros Irrigation System in Huesca, Spain. *Geographical Analysis*, **23 (1)**, 5-41.

Fishburn, P.C. (1982). *The Foundations of Expected Utility*. Dordrecht, Holland: Reidel Publishing Company.

Gómez-Limón, J.A. and Berbel J. (2000). Multicriteria Analysis of Derived Water Demand Functions, A Spanish Case Study. *Agricultural Systems*, **63 (1)**, 49-71.

Gómez-Limón, J.A. and Arriaza, M. (2000). Socio-Economic and Environmental Impact of Agenda 2000 and Alternative Policy Choices for Market Liberalisation on an Irrigated Area In North-Western Spain. *Agricultural Economics Review*, **1 (1)**, 18-30.

Hall, D.C. (ed.). (1996). *Advances in the Economics of Environmental Resources. Vol. 1. Marginal Cost Rate Design and Wholesale Water Markets.* Connecticut: JAI Press, Greenwich,.

Hardaker, J.B., Huirne, R.B.M. and Anderson, J.R. (1997). *Coping with Risk in Agriculture*. Oxford: CAB International.

Hazell, B.R. and Norton, R.D. (1986). *Mathematical Programming for Economic Analysis in Agriculture*. New York: MacMillan.

Huirne, R.B.M. and Hardaker, J.B. (1998). A Multi-Attribute Utility Model to Optimise Sow Replacement Decisions. *European Review of Agricultural Economics,* **25 (4)**, 488-505.

Hwang, C.L. and Yoon, K. (1981). *Multi-Attribute Decision-Making*. New York: Springer-Verlag.

Keeney, R.L. (1974). Multiplicative utility functions. *Operations Research,* **22 (1)**, 22-34.

Montginoul, M. and Rieu, T. (1996). Instruments de gestion de l'eau d'irrigation en France, exemple de la Charente. *Ingénieries-EAT*, **8 (1)**, 3-12.

Naredo, J.M. and Gascó, J.M. (1994). Spanish Water Accounts. Environmental Policy Committee (ENV/EPOC/SE/A(94).2). París: OECD.

OECD (1999). *The Price of Water Trends in OECD Countries*. Paris: OECD.

Qureshi, M.E., Harrison, S.R. and Wegener, M.K. (1999). Validation of Multicriteria Analysis Models. *Agricultural Systems*, **62 (1)**, 105-116.

Randall, A. (1981). Property Entitlements and Pricing Policies for a Maturing Water Economy. *The Australian Journal of Agricultural Economics*, **25 (3)**, 195-220.

Romero, C. and Rehman, T. (1989). *Multiple Criteria Analysis for Agricultural Decisions.* Amsterdam: Elsevier.

Segura Graíño, R. (1997). *Reflexiones y estimaciones sobre el coste del agua de riego*. XV Congreso Nacional de Riegos. Lleida.

Spulber, N. and Sabbaghi, A. (1994). *Economics of Water Resources, from Regulation to Privatization.* Boston: Kluwer Academic Publishers.

Sumpsi, J.M., Amador, F. and Romero, C. (1997). On Farmers' Objectives: a Multi-criteria Approach. *European Journal of Operational Research* **96 (1)**, 1-8.

Tsur, Y. and Dinar, A. (1995). *Efficiency and Equity Considerations in Pricing and Allocating Irrigation Water*. Policy Research Working Papers n. 1460. World Bank, Washington.

Varela-Ortega, C., Sumpsi, J.M., Garrido, A., Blanco, M. and Iglesias, E. (1998). Water Pricing Policies, Public Decision-making and Farmers' Response: Implications for Water Policy. *Agricultural Economics*, **19 (2)**, 193-202.

Wahl, R. (1989). *Markets for Federal Water, Subsidies, Property Rights and the U.S. Bureau of Reclamation.* Washington: Resources for the Future.