INTEGRATING AGRICULTURAL POLICIES AND WATER POLICIES UNDER WATER SUPPLY AND CLIMATE UNCERTAINTY

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ABSTRACT

The interactions of water policies and agricultural policies are increasingly determinant for achieving an efficient management of water resources in many countries. In the EU, agricultural and environmental policies are seeking to converge progressively towards mutually compatible objectives and, in this context, the recently reformed Common agricultural Policy (Agenda 2000) and the EU Water Framework Directive constitute the policy framework in which irrigated agriculture and hence water use will evolve. In fact, one of the measures of the European Water Directive is to establish a water pricing policy for improving water use and attaining a more efficient water allocation. The aim of this research is to investigate the irrigators' responses to these changing policy developments in a self-managed irrigation district in Southern Spain. For this purpose, we have developed a stochastic programming model that estimates the farmers' responses to the application of water pricing policies in different agricultural policies scenarios when water availability is subject to varying climate conditions and water storage capacity in the district's reservoir. Results show that irrigators are price-responsive but a similar water-pricing policy could have distinct effects on water use, farmers' income and collected revenue by the water authority in different agricultural policy options. Water availability is a determinant factor and pricing policies are less effective for reducing water consumption in drought years. Thus, there is a need to integrate the objectives of Water Policies within the objectives of the CAP programs to avoid distortion effects and to seek a synergy between these two policies.

Keywords: agricultural policies, water policies, water pricing, stochastic programming.

INTRODUCTION

Water is a scarce resource in the Mediterranean basin and the agricultural sector is the largest user of water. Spain's irrigated agriculture consumes close to 80 per cent of the total available water resources in the country but it extends over 3.6 million ha that, being the largest irrigated surface in the EU, it constitutes a mere 18% of the total cultivated lands. However, irrigated crops account for 60% of all agricultural production and 80% of farm exports. Thus, irrigation water has become an essential input to sustain agricultural activity and therefore a more efficient water management is progressively required.

Spain is divided into eight different publicly-owned and independently managed river basin authorities that are responsible for water management in the basins and for delivering water to the irrigation districts. The irrigation districts are well established Water User Associations that allocate water among its members. Water in Spain is of public ownership, including underground waters, and irrigators have the right to use water under non-tradable concessions, granted by the public authority, that determine their water allotments.

In Spain as in other Mediterranean countries increasing water shortages in many regions have called for a progressive implementation of water policies that will ameliorate water management and increase water use efficiency.

In fact, several water policies have been proposed for this purpose in Spain and elsewhere such as pricing policies (Varela Ortega et al. 1998; Tsur and Dinar 1997; Dinar and Subramanian, 1997, Rosegrant et al 1995, among others), water markets (Garrido, 1998, Rosegrant and Binswanger, 1994), water rights adjustments (Sumpsi et al.,1998) and financial incentives (Spencer and Subramanian, 1997) .

On the other hand, the EU agricultural sector is strongly determined by agricultural policy programs aimed to secure farmers' income and protect the rural environment. Thus, the irrigated agricultural sector in Spain as in other EU countries is influenced by two types of policies: Agricultural Policies and Water Policies. The "Agenda 2000" reform of the Common Agricultural Policy (CAP) and the European Water Framework Directive (WFD) constitute a new policy context for the development of the irrigated agricultural sector and hence for water use in the agricultural sector. The aim of the Agenda 2000 CAP reform is to procure a multifunctional, sustainable and competitive agriculture throughout the EU territory. This new Agenda 2000 CAP reform, based on the establishment of production-related direct aid payments, gives a prominent role to agri-environmental instruments to support a sustainable development of rural areas and to respond to society's increasing demand for environmental services. Alongside, Rural Development measures seek to stabilize and support rural communities by further integrating environmental and socio-economic aspects as Member States are given the option condition the access to the CAP aid payments to meeting certain environmental requisites (cross-compliance option). This tendency is being further reinforced in the recently proposed and strongly debated Midterm Review of the CAP.

On the other hand, the EU Water Framework Directive (WFD) 2000/60/EC enacted in 2000 has established a Framework for Community action in the field of Water Policy and represents an important step towards sustainable use of water resources in the EU . The WFD proclaims an integrated management of all water resources by establishing river basins as the basic unit for all water planning and management actions. In addition, the WFD requires Member States to undertake an economic analysis of water use (article 5) and stipulates that all Member States must take into account the principle of recovery of the costs of water services, including environmental and resource costs, in accordance with the polluter pays principle (article 9). For this purpose, Member States shall ensure by 2010 that water-pricing policies will provide adequate incentives to use water resources efficiently. Unquestionably, the implementation of the WFD will have important consequences in the irrigated agricultural sector of the EU.

OBJECTIVES OF THE RESEARCH

In this context, the aim of this research is to predict the irrigators' response confronted to the combined application of water policies and agricultural polices. We analyze comparatively the effects of the implementation of a water pricing policy, defined by the application of volumetric water charges, in different agricultural policy alternatives. In this combined policy context, we have also taken into account the different water availability situations that farmers face that constitute one of the major sources of uncertainty for attaining the farmers' programmed production plan. Water availability is determined by varying climate conditions and storage capacity in the district's reservoir. Specifically, the analysis focuses on the evaluation of the effects of these policies on water use, farmers' income and on the revenue collected by the water management agency. In particular this paper will address the changing strategies that farmers will follow when water-pricing policies are applied in conjunction with agricultural policies as envisaged in the new EU policy context. That is, changes in the cropping pattern, land allocation between irrigated and rain fed farming, cropping intensification and management of water in the farm. All these issues are intended to throw some light into the difficult task that the EU as other countries elsewhere are facing to integrate water conservation policies and agricultural policies.

METHODOLOGY

The model

To analyze the impacts of the integrated application of agricultural and water policies, we have built a Discrete Stochastic Programming Model (DSPM) that simulates the farmer's behavior in different policy scenarios. The model takes into account the uncertainty that farmers face on water availability along their decision making process in a given cropping season (Apland et al, 1993; Taylor et Young, 1995; Torkamani et Hardaker, 1996; Jacquet et Pluvinage, 1997; Keplinger er al., 1998; Blanco 1999). In fact, risk analysis in farmer economic behavior models has become an essential element for models to be useful.

We find in the literature several mathematical programming techniques that take into account different sources of risk and uncertainty (Hazel and Norton, 1986; Rae, 1994; Hardaker, J.B., 1997). We also know that most of the decisions in agricultural production are taken in a sequential way (Rae, 1971; Antle 1983,b; Adesina et al, 1991; Taylor and Young (1995); Torkamani and Hardaker, 1996). We consider that dynamic models can be more valid than static models to understand risk effects in agricultural production (Antle, 1983 b). The Discrete stochastic programming model (DSPM), developed by Cocks (1968) and Rae (1971), allows to solve a multi-stage decision process in which the decision maker's knowledge about random events changes through time as economic choices are made.

Uncertainty in water availability

Sumpsi et al. (1996), and Blanco (1999), show that the main source of risk in the southern Spanish irrigated agriculture is water availability. Water availability for irrigation in these areas depends on climatic conditions along the crops' growing period and on the amount of water collected in dams and reservoirs. Following this line, the main assumption in our analysis is that farmers make their production choices over time based on their knowledge about the amount of water that will be delivered from the dam and on existing climatic conditions.

Model structure

The model (represented in Figure 1) is defined by three decision stages and it assumes full knowledge of the past, three "states of nature" for stage two and nine for stage three. The different "states of nature" are defined by the combination of two random variables, namely the volume of water available from the reservoir and the climate conditions. We have considered three levels of water volumes delivered from the district's reservoir (S1, S2, S3) and three different climatic situations (A1: humid year, A2: average year, A3: dry year) according to statistical information. Spring rainfall has been taken as the reference climatic condition. The combination of these variable along the decision making process generate nine final 'states of nature' (A1S1, A2S1, A3S1,…)

The farmers decision process is represented as follows: (i) In the first stage farmers take their crop allocation decisions for winter crops prior to their knowledge of the year-long climate conditions and of the water that will be actually delivered from the district's reservoir (which is decided in the spring). Thus, in this stage farmers decide what to crop in the winter time considering their expectations on water availability. (ii) In the second step, decisions concerning the surface assigned to spring crops are taken according to the farmer's knowledge of the water that will be released from the reservoir. (iii) Finally in stage three farmers decide on the specific irrigation production techniques (intensive and extensive) once they have precise information on the actual climatic conditions, that is the spring rainfall, that will determine crop yields.

The model maximizes the expected farmer's income under different constraints (technical constraints, economic constraints and policy constraints).

- The objective function is:

$$\text{Max} \quad E(Z) = \sum_{s.a} P_s P_a Z_{sa} \tag{1}$$

where Z_{sa} is the farmer's income in the sate of nature *sa*, and $p_s\ p_a$ are the probabilities of the different states of nature.

- Farmers' income is defined by:

$$Z_{SA} = X3\,j,k,r,t,s,a * (Y\,j,k,r,t,a * P_j + sub_j) - CIRR_{S,A} - CMO_{S,A} \tag{2}$$

where subindex *j* accounts for crop type, *k* for soil quality, *t* for the irrigation production technique, *r* for the irrigation technique (gravity, drip irrigation) and *sa* for the different states of nature; X3 is the crop surface in the last step of the decision-making; Y j,k,r,t,a is crop yield; P_j is crop prices; sub_j are product subsidies; $CIRR_{S,A}$ are water application costs; $CMO_{S,A}$ are labor costs.

- Total water application costs CIRR s,a are composed of four elements:

$$CIRR_{s,a} = C_X S + C_q Q\ s,a + C_r S_r + C_{ar} I_r \tag{3}$$

C_x: Fees paid by the irrigators to the water authority in the river basin (€/ha), C_q: is a variable volume charge (€/m^3), C_r: Irrigation equipment maintenance costs (€/ha), C_{ar}: Repayments of the investment in irrigation equipment (€/ha)

The objective function is subjected to the following constrains (omitting labor, production possibilities, and policy constraints):

- Availability of land:

$$\sum_{j}\sum_{k}\sum_{t} X3_{j,k,r,t,s,a} \le S_k \qquad (4)$$

where S_k represents the surface by soil quality

- Irrigation equipment:

$$\sum_{j}\sum_{k}\sum_{t} X3_{j,k,r,t,s,a} \le S_r + I_r \qquad (5)$$

where S_r is the initial irrigation equipment and I_r accounts for investment in irrigation requirements.

- Irrigation restrictions:
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$$\sum_{j}\sum_{k}\sum_{r}\sum_{t} be_{j,k,r,t}\, X3_{j,k,r,t,s,a} \le Q_{s,a} \qquad (6)$$

$$Q_{s,a} \le D_s * h \qquad (7)$$

where $be_{j,k,r,t}$ are the crop water requirements, $Q_{s,a}$ is water availability in the state of nature *sa*, h is a water distribution efficiency parameter and D_s is water allotment in the state of nature *s*.

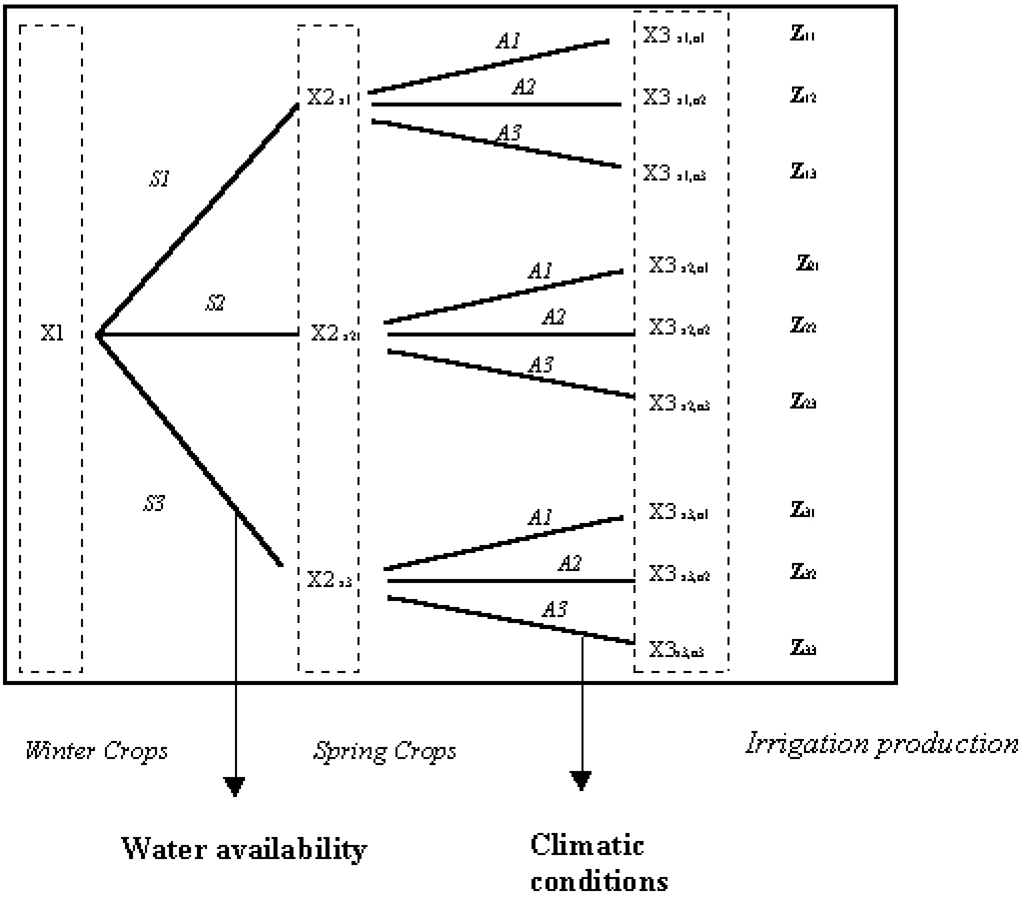

Figure 1. Decision Tree.

The zone of study

For the empirical application of this study, we have selected the irrigation district *El Viar,* a medium-size Water Users Association (WUA) that extends over 11,958 ha in the Guadalquivir river basin in the region of Andalusia in Southern Spain. The district is an old self-managed irrigation district established in 1958 constituted by 3,978 farms where the average holding size is 10 ha. Water supply depends on the storage capacity of a reservoir directly managed by the own district .

Main crops grown are cereals, cotton, sunflower, vegetables and fruit trees. Irrigation techniques used are mainly gravity and drip irrigation and the average water allotment right for the farmers in the district is around 6000 m^3/ha, which may vary considerably depending on water availability conditions. Irrigators pay a fixed fee of 102.17 € per ha to cover partially the costs of distribution, maintenance of infrastructure and administration. Historically, this irrigation district has suffered from water scarcity in drought periods as well as the nearby city of Seville and therefore public water authorities are considering water conservation practices in the irrigated agriculture as a major objective (Iglesias et al., 2000).

For the purpose of the analysis, the irrigation district has been characterized by a typology of four representative farms (F1,F2,F3,F4) (Table 1), that represents the irrigation agriculture in the area. The representative farms were selected according to farm size, soil quality, water availability, crops grown and irrigation technique. The technical and economic parameters of the representative farms have been obtained from a survey conducted in the study area (Sumpsi et al., 1998) and further revised to adjust to the new policy conditions (2001)

Table 1. Farm typology.

Farm type	**Area (ha)**	**Soil quality (%)**	**Irrigation technique (ha)**	**Cropping pattern (%)**
F1	5	K1: 60% K2: 40%	Gravity: 4 Drip: 1	Cotton 20%,Vegetables 29%, Sugar beet 20 %,Others 31%
F2	40	K1: 100%	Gravity: 30 Drip: 10	Cotton 34% ,Vegetables 4.5%, Others 40% Sugar beet 20%, Fruit trees 1.5 %
F3	40	K1: 40% K2: 60%	Gravity: 30 Drip: 10	Cotton 34%,Vegetables 7% ,Others 40% Sugar beet 19%, Fruit trees 4.5%
F4	100	K1: 50% K2: 50%	Gravity: 70 Drip: 30	Cotton 15%, Corn 15% Fruit trees 10%, Others 30%, Wheat/sunflower 30%

Source: Sumpsi et al. (1998)

Policy options

We have defined three policy options within the framework of the CAP: (i) CAP reform of 1992, (ii) Agenda 2000 measures currently applied in the area and (iii) the establishment of equal direct payments for all crops decoupled from crop yields (calculated to maintain the same level of aid payments as in Agenda 2000) . This scenario represents the trend followed by EU policies towards production-neutral payments (to comply with the WTO agreements) and it can be considered a first step to the complete decoupled payments envisaged in the recent midterm review of the CAP . For all agricultural policy options considered he have simulated jointly the application of a water pricing policy defined by administered volumetric water charges. Consequently, we will be able to study the interactions between the implementation of agricultural and water policies. The policy scenarios are summarized in table 2.

Table 2. Policy Scenarios.

AGRICULTURAL POLICY OPTIONS (*)	**POLICY INSTRUMENTS**	
	PRICE SUPPORT	**DIRECT PAYMENTS**
(E1) CAP REFORM 1992	High price support	Low direct payments tied to crop yields
(E2) AGENDA 2000	Low price support	High direct payments tied to crop yields
(E3) EQUAL AID PAYMENT	Low price support	Equal direct payments for all crops independent of crop yields

(*) For all policy options a water policy has been simulated defined by volumetric water prices (a charge per volume applied, t €/m^3)

RESULTS

The effects of water availability and climate uncertainty

In all agricultural policy scenarios, water demand in water scarcity scenarios is very inelastic (figures 2,3,4). Thus, water consumption in dry periods (low water supply from the reservoir and drought year) is not significantly reduced until prices reach high levels but farm income is negatively affected. Farmers' rigidity to adapt to water scarcity situations prevails across all policy options. Agenda 2000 shows as like more inelastic demand as prices have to mount 0.13 €/m^3 to reduce water consumption (as compared to 0.11 €/m^3 in the 1992 CAP scenario and 0.09 €/m^3 in the Equal Aid Payment scenario).

In an average year, farm income decreases by 3 % in the Agenda 2000 option, but in drought years this reduction doubles to 6.14%. Thus, farmers capacity to adapt to water scarcity situations is based on their possibilities to change the cropping pattern, which are substantially reduced in the Agenda 2000 scenario. In fact, low-water demanding crops such as oil seeds are less profitable in Agenda 2000 .

The combined effects of agricultural policies and water policies

Pricing policies have been simulated to cover an ample range of price rates (ranging from 0 €/m^3 to 2 €/m^3 when water use equals zero, in 48 simulation levels). For the purpose of clarity we have summarized the results selecting three levels of water prices, including the price levels that will recover the O&M costs. Cost recovery is considered a crucial issue as the WFD considers the introduction of a water pricing policy that will ensure an efficient use of water taking into account the principle of cost recovery for water services.

The price levels selected are:

- P_1= No water pricing policy. Farmers pay a fixed fee of 102.17 €/ha. This fixed fee is composed by different elements: the *basin agency fees* that cover the capital, operation and maintenance cost of the state financed infrastructure and the *irrigation district fee* intended for the operation and maintenance cost of the irrigation district.
- P_2= water price to recover the total O&M costs of the irrigation district (237.27 €/ha)
- P_3= water price that maximizes the district's revenue

Table 3 shows the aggregate results of the effects on water consumption, farm income, and the revenue collected in the irrigation district. Table 4 shows the results of the cropping patterns chosen by the farmers in the simulated scenarios. Figure 5 depicts the revenue collected and the cost recovery level for all policy options simulated.

Water Demand according to availability of water

Figure 2. 1992 CAP scenario.

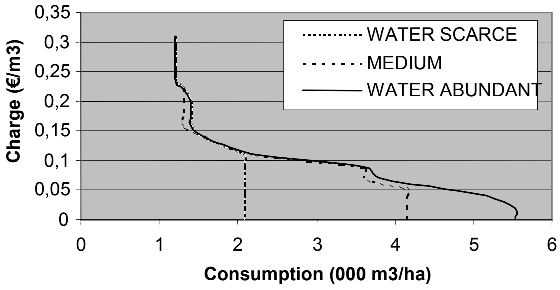

Figure 3. Agenda 2000 CAP scenario.

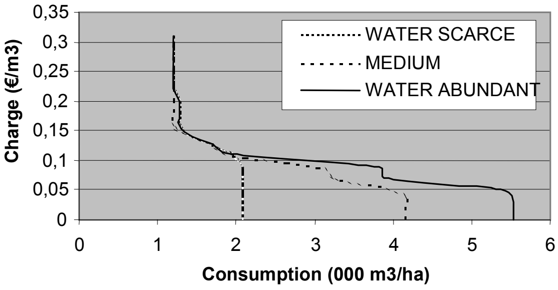

Figure 4. Equal Aid Payment scenario.

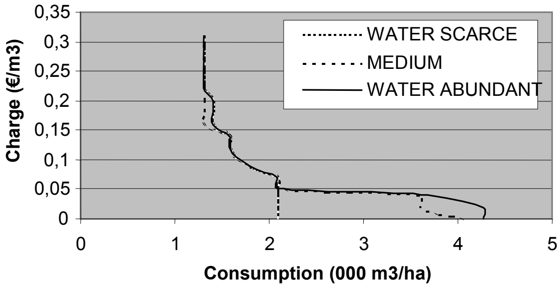

Table 3. Results of policy options (average state of nature).

CAP	Tariffs	Water consumption		Farm Income		Irrigation district revenue	
		m^3/ha	%	€/ha	%	€/ha	%
PAC 92	P_1=0 €/m^3	3.81	100	1474.64	100	101.03	100
	P_2=0.04 €/m^3	3.75	98.4	1339.54	90.8	236.32	233.91
	P_3=0.09 €/m^3	2.88	75.6	1160.91	78.7	360.31	356.64
AGENDA 2000	P_1=0 €/m^3	3.81	100	1431.37	97.1	101.03	100
	P_2=0.05 €/m^3	3.54	92.91	1232.80	83.60	281.57	278.69
	P_3=0.09 €/m^3	3.08	80.8	1117.10	75.7	364.93	361.20
Equal Aid Payment	P_1=0 €/m^3	3.22	84.5	1481.55	100.5	101.03	100
	P_2=0.07 €/m^3	1.78	46.72	1283.84	87.06	249.83	247.28
	P_3=0.14 €/m^3	1.33	41.5	1164.42	78.9	324.55	258.77

Table 4. Cropping pattern selection by policy option (%).

CAP	Tariffs	Wheat	Corn	Sunflower	Cotton	Irrigated Surface
PAC 92	P_1=0 €/m^3	10	19	16	25	95
	P_2=0.04 €/m^3	10	20	16	24	95
	P_3=0.09 €/m^3	29	20	0	5	80
AGENDA 2000	P_1=0 €/m^3	10	14	0	35	82
	P_2=0.05 €/m^3	22	13	0	35	93
	P_3=0.09 €/m^3	38	0	0	35	96
Equal Aid Payment	P_1=0 €/m^3	10	19	16	25	95
	P_2=0.07 €/m^3	10	20	16	24	95
	P_3=0.14 €/m^3	29	20	0	5	80

In the 1992 CAP reform scenario (E1) (reference scenario), water use is high (almost 4000 m3/ha) and farmers grow a high proportion of water-demanding crops such as cotton, corn and vegetables. When water charges are applied in this scenario, water use is only slightly reduced by 2 % but farmers' income will decrease by 10%. O&M costs will be recovered only if water prices increase beyond 0.04 €/m3, well below the water price that will maximize the district's revenue (0.09 €/m3). In addition, as water prices rise, farmers grow less water-demanding crops such as wheat, sunflower and the irrigated surface will be progressively reduced.

Compared to the reference scenario, Agenda 2000 (E2) will not induce water use reductions. However, total irrigated surface will decrease by 13% as traditional crops such as sunflower and corn will diminish and farm income will decline slightly (3%). When water prices are charged in this scenario, farmers will tend to adopt water saving strategies by cropping less water demanding crops. In addition, recovering O&M costs will require prices to mount to 0.05 €/m^3 as water consumption will be further reduced by 7 % and farmers' income by 13 %. Thus cost recovery policies will have greater effects in this scenario.

The Equal Aid Payment Policy (E3) will achieve a substantial reduction in water consumption even without applying any water policies, as opposed to the other policy options. Comparatively to the reference scenario, water demand will decline by 15.5 % but the irrigated surface will remain constant. This means that crops with low water requirements will be cultivated in the irrigated lands. However, this policy alternative will induce a crop specialization towards wheat production and other crops such as corn and sunflower, traditionally grown in the area, will disappear. Wheat production will be profitable and hence farm income will increase slightly (1%). Water policies are very effective in this scenario for attaining water saving objectives. When water charges are applied, price rates have to mount to 0.07 €/m^3 to recover O&M costs and this will in turn decrease water demand by 38 % but farm income will decrease proportionally less (13 %). The revenue collected in the district will continue to rise and will reach a maximum at 0.14 €/m^3.

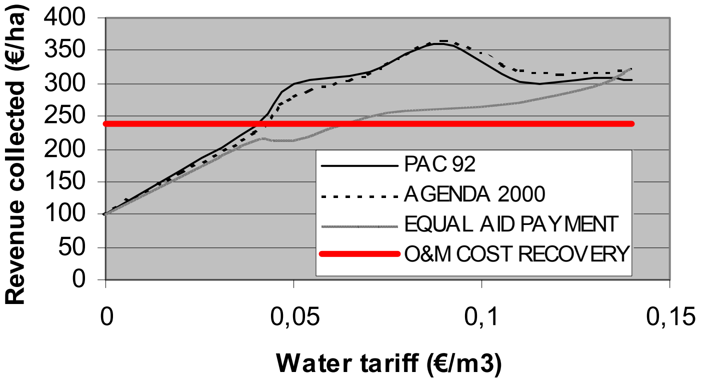

Figure 5. Average irrigation district revenue in the agricultural policy scenarios.

CONCLUSIONS

- Results show that a water pricing policy based on volumetric charges could have a low impact on water consumption in dry years. In fact, the analysis reflects that when water availability is low, water demand is very inelastic for low price ranges. Water consumption will start to decrease only if prices mount considerably. Thus, it indicates that this water policy will not produce the desired effects of water conservation in the case of drought.
- In addition, full recovery of O&M cost will be attained at different water charges in each agricultural policy scenarios. Thus, the effects of these water charges will be different across agricultural policies, as strategies followed by the farmers will vary accordingly. That is, cropping patterns will change in each agricultural policy context when full recovery of O&M costs is attained. Within the water price range selected (full recovery of O&M costs up to the maximum revenue collected by the water district), we can observe that the price interval is wider in the Equal Aid Payment scenario. This will permit a more flexible integration of Water Policies and Agricultural Policies when payments received by the farmers are decoupled from production levels. This can be considered as a positive effect of the widely discussed decoupled policies within the EU context. However it can not be generally argued that this policy is unquestionably beneficial. We have observed from the discussion of the results that the application of an equal direct payment for all the crops may produce also negative environmental effects such as the reduction of crop diversity.
- The implementation of an Equal Aid Payment Policy, neutral from production, will attain the objective of water conservation and farmer's income maintenance more efficiently than the other policy alternatives. In this policy scenario water is reduced without inflicting any income loss to the farmers who in fact attain a slightly higher income. In the other policy options water conservation objectives are only met at the cost of incurring in farm income reductions.
- With respect to the policy option currently applied in the area studied, Agenda 2000, it is expected that the introduction of water pricing policies will produce certain detrimental effects on framers income and water will not be substantially reduced. Thus, to avoid this distortion, the application of the European Water Directive will need to be done in accordance with the CAP programs and specifically with the CAP agri-environmental measures.
- As we have already argued, a similar water-pricing policy could have distinct effects in different agricultural policy options. Thus, it can be concluded that there is a need to integrate the objectives of the EU WFD with the objectives of the CAP programs to avoid distortion effects and to seek a synergy between these two policies. In this way, the use of cross compliance introduced in the "Agenda 2000" CAP reform, that enables member States to condition the CAP direct payments to meet certain environmental conditions, could be a good opportunity to integrate the WFD objectives into agricultural policies.
- In this analysis we have tried to bring some understanding to the difficult task of integrating agricultural policies and water resources policies, to attain the dual objective of maintaining farmers income and conserving water resources and environmental sustainability. This is a crucial undertaking in many areas in the world where water availability is a major problem such as the Mediterranean region.

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