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WATER POLICIES AND AGRICULTURAL POLICIES: AN INTEGRATION CHALLENGE FOR AGRICULTURAL DEVELOPMENT AND NATURE CONSERVATION

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Abstract

In the Mediterranean basin, irrigation agriculture is a key sector for the economy but it consumes a large proportion of all available water resources. This situation is producing an ever-mounting depletion of water resources and degradation of valuable aquatic ecosystems. In southern countries of the EU competing uses of water for agricultural production and for providing ecosystem services is calling for a revision of former water policies and for an integration of agricultural and water policies. This research focuses on the comparative effects of water polices and agricultural policies aiming to conserve water resources in an area of Spain's southern central plateau in the region of Castilla-La Mancha. In this area, agricultural production is dependent solely on groundwater and, as a consequence of lucrative CAP production-related payments, water abstractions have exceeded the recharge capacity of the aquifer. The induced over-exploitation of the aquifer has lead to long-lasting social conflicts as well as acute environmental concerns due to the derived degradation of natural wetlands of high ecological value. Regional, national and European policies have been implemented with the purpose of solving these conflicts, but the solution has not been found so far. Based on an integrated vision of water resources management, the methodology of this study consists in the integration of an agro-economic model and a hydrology model. The economic model is a farm-level mathematical programming model of constrained maximization that simulates farmers' behavior confronted to different policy scenarios. The hydrology model (WEAP, water evaluator and planning system) permits to up-scale the results of the MPM to the basin's level to assess the effects on the aquifer of the selected policies. Based on an ample field work several policy scenarios have been chosen and simulated to analyze the impacts that the different policy options would have on the different components of the system. Results of the integrated economic and hydrology models, show that all current water conservation policies applied in the area (Upper Guadiana basin), even when they can contribute to an important reduction in water consumption, will not be able to attain the recovery of the aquifer unless other additional measures, aiming to reduce water abstractions, are put into practice. We can also conclude form the stakeholders' perspective that a more integrated and coordinated application of water policies and agricultural policies is a key issue to meet the dual objective of maintaining farming activity and protecting the wetland ecosystems. In the current EU context of the WFD and the CAP larger and well targeted public participation will contribute to ensuring an effective and socially acceptable water resources management in the area.

Keywords: Water policies, irrigation, agricultural policies, mathematical programming model, hydrology models.

1. Introduction: the policy context

Irrigation expansion and nature conservation: A policy-driven evolution

Competing access to water resources among sectors and regions and derived social conflicts are widespread throughout arid and semiarid countries worldwide. One of the world examples is the Mediterranean basin in which irrigation expansion has been a key driver for developing the agricultural sector and the rural livelihoods (Benoit and Comeau, 2005). Alongside with the development of publicly funded surface irrigation networks and water storage infrastructure, groundwater irrigation has expanded progressively under private initiative by a countless number of individual farmers. This has been the case of Spain's Mediterranean littoral and its southern hinterland, where groundwater is the main source of water for irrigation. Its mounting expansion over the last decades has been the response of easily accessible modern drilling and pumping technologies for many individual farmers, low cost of irrigation equipment, lucrative farming activity and the higher resilience of subterranean waters to climate variability (Llamas and Martinez Santos, 2006; Mukherji, 2006; Varela *et al.*, 2007). However, ground-water based economic and social development has come along with significant environmental damage to aquatic ecosystems giving rise to acute social conflicts as environmental awareness expands progressively in society (Rosegrant *et al.*, 2002; Comp.Asses.Wat.Mng, 2007, Martinez Santos *et al.*, 2007).

The Upper Guadiana basin in Spain's inland region of Castilla La Mancha provides a valuable example of such a conflicting outcome that has persisted over the years. Intensive use of groundwater has offset the everlasting drought problems in the area and has given rise to an irrigation-based thriving economy of a once stagnated region. Yet, water pumping has led to the overexploitation of the Western La Mancha aquifer and the progressive degradation of the Ramsar-catalogued and UNESCO Biosphere reserve wetland ecosystem of the national park 'Tablas de Daimiel' (Varela and Sumpsi, 1999; Baldock *et al.*, 2000; Ramsar, 2006; MIMAM, 2006).

Two main public policy bodies affect directly and indirectly water consumption in the Upper Guadiana basin, water policies and agricultural policies. Strong evidence supports that irrigation expansion has been and still is, primarily, a policy-driven outcome (Varela, 2007). Past programs of the Common Agricultural Policy (CAP) during the 70's and 80's based on production-related subsidies have encouraged irrigation intensification. Hence, overpumping occurred in the large 5000 km2 WLM aquifer and reached up to 500 Hm3 (million cm) surpassing its natural recharge rate set at 230 Hm3 (CHG, 2006). As return flows diminished and the water table lowered considerably, the aquifer was declared officially overexploited in 1991 (MOPTMA, 1995). Salinization and contamination affected groundwater quality and eutrophication of surface water flows brought about changes in the autochthonous vegetation and pit fires emerged as flooded lands remitted. With the aim of finding a remedy to this ecological impact, the River Basin Authority (RBA) adopted a Water Abstraction Plan (WAP) in 1991 based on the imposition of a strict water quota regime with no compensation to the farmers for their derived income loss. Water quotas were established based on farm size, larger farms having a smaller volume (see table 1).

Table 1. Water Abstraction Plan (Permitted Water Quotas) (2006)

Water Abstraction Plan Water Quotas 2006	
ha	m3/ha
0-30	2640
30-80	2000
> 80	1200
vineyard	1000

Source: CHG (2006)

The quotas reduced considerably the entitled historical water rights of the irrigators from an average of 4,200 cm per ha to 2,000 cm per ha. This policy has created a long-lasting social unrest and free-riding behavior among irrigators with uncontrolled drillings. The Water Administration not being capable of enforcing the policy to its full application, due to the large social costs implied. This situation is common to other world examples in which the difficult control of ground water drillings in an open-access common-pool resources structure entails high enforcement costs to the public authorities (Provencher and Burt 1994; Shah *et al.*, 2000; Schuyt 2005; Schlager and López-Gunn 2006; Llamas and Martinez-Santos 2006; McCann *et al.*, 2005).

In parallel, as the CAP evolved to include progressively environmental considerations, a special 5-year Agri-environmental program was launched in the area following the reform of 1992. The AEP established a quota system that compensated the farmers for their derived income if they joined voluntarily the reduction of their entitled water volumes (establishing a 50%, 70% and 100% reduction level and the correspondent compensation payments as shown in table 2).

Table 2. Evolution of the EU Agri-Environmental Program

EU Agri-Environmental program of Western La Mancha aquifer Income Compensation Payments					
Level of w. consumption reduction %	**1st Phase (1993-2002): AEP₁** Payments: independent of farm size €/ha			**2nd Phase (2003-2007): AEP₂** Payments: modulated according to farm size €/ha	
	1993	1997	2001	2006	
50 %	156	164	179	1- 40 ha	209
				40-80 ha	125
				> 80 ha	63
70 %	258	271	296		
100 %	360	379	414	1- 40 ha	518
				40-80 ha	311
				> 80 ha	155

Source: JCC-LM (2006)

The program was extended up to 2002 and was joined by a majority of the irrigators, covering an overall area in the mid 90's close to 100,000 ha (out of the 150,000 total irrigated lands) an met, consequently, the objectives of reducing the annual water abstractions to about 270 Hm3 (even below the 320 Hm3 target) (JCC-LM, 1999). However, the program entailed high public costs and a considerable burden to the EU budget and its cost-effectiveness was questioned (Iglesias 2001; Varela, 2007;). In 2003 the AEP program was reformed responding to the increasing environmental concerns within the CAP. Water quotas were reduced further with respect to the irrigators' initial water rights as percent volume reductions were based on the existing national WAP quotas. The EU EAP policy and the national WAP were coupled of the first time under a common objective of recovering the Western La Mancha aquifer. In the new AEP income compensation payments were barely covering farm income loss from less water being available for farming. Therefore the program was abandoned by a large proportion of the farmers and extended over just about 19,000 ha (CHG, 2006) which made the program no longer valid for accomplishing the water mining reductions target in the overall aquifer.

At present, the EU Water Framework Directive (2000/60/EC), enacted in 2000 as the first comprehensive basin-based integrated water policy in Europe, requires all member states to achieve 'good ecological status' of all watercourses by 2015. In consequence, the RBA is committed to achieve a maximum annual water volume diverted to the agricultural sector of 200 Hm3 to assure the aquifer's recharge over a certain time span. The Special Plan of the Upper Guadiana (SPUG), recently approved by the Spanish parliament (CHG, 2007), reflects this objective. The SPUG includes different types of measures, such as purchasing water rights from the irrigators in the newly created Water Rights Exchange Center, a social restructuring plan that includes the legalization of illegal wells, the closing-up of un-licensed bores, a reforestation plan and the support of extensive rainfed farming. The water saving plan that will be accomplished in one of the RBA scenarios is shown in table 3.

Table 3. SPUG measures to be applied in the WLM from 2007 to 2027.

SPUG measures (2007-2027)	**Water volume recovered in the WLM aquifer (Hm³)**
1. Water Rights Exchange Center	144
→ Legalisation of illegal wells	-32
2. Reforestation plan	96
3. Management and control measures	48
4. Agricultural measures	16
Total	272

Source: CHG (2007)

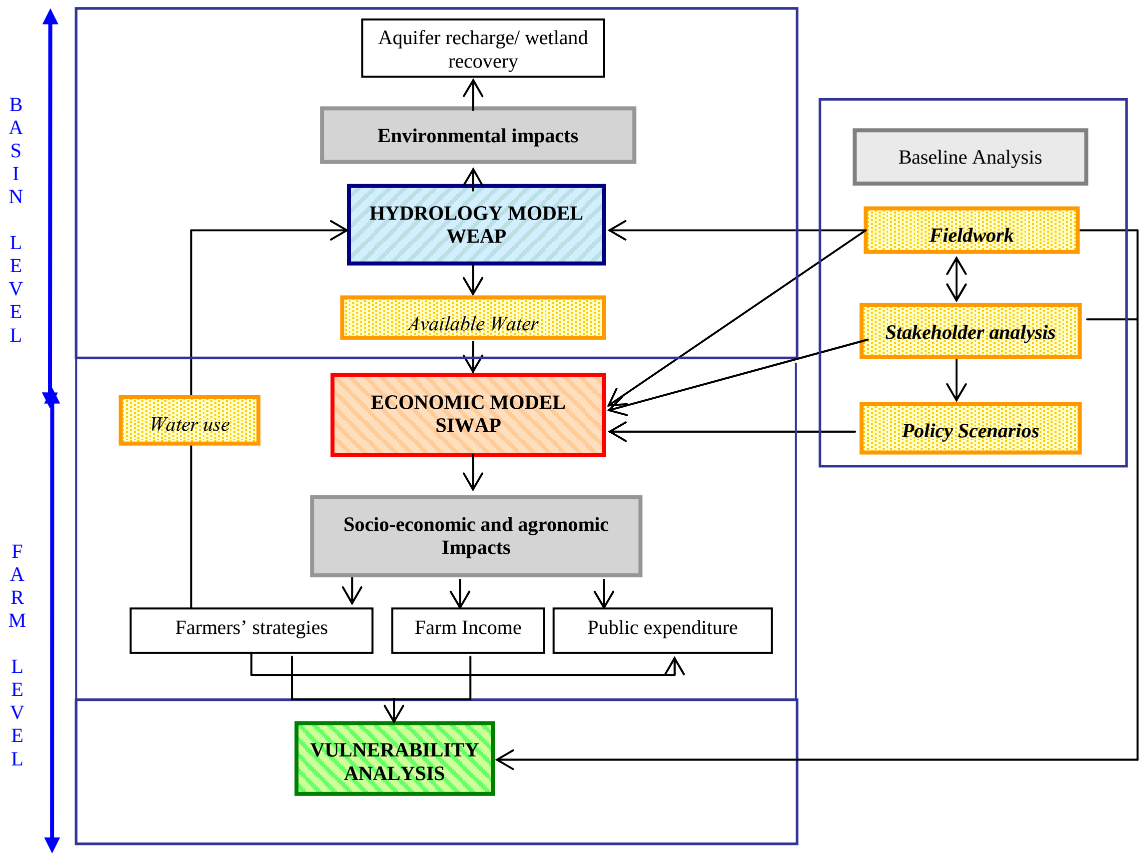
Clearly enough, agricultural policies and water policies, both EU and regional, share the common objective of natural resources conservation. As the forthcoming reform of the CAP (the CAP 'health check') that is being now discussed in the EU Commission makes a step forward by including water management and climate change as specific requirements in its future programs. Yet, the CAP requires also ensuring a sustainable, competitive and multifunctional agriculture. In the Guadiana basin, the long-lasting lack of integration and mismatching of agricultural and water policies has frequently resulted in non-coherent and disruptive outcomes, presided by social unrest in the rural communities. Then a further integration of these two types of policies is a major challenge for adapting to new forms of water management.

In this context ***the objective of this research*** is to analyze the comparative environmental and socio-economic effects of the joint application of agricultural policies and water policies in the Upper Guadiana basin. How these policies will interact to reach the dual objective of conserving water resources and maintaining the socio-economic activity in the area is a long term outcome. For this reason the research focuses, in the first place, on a short term analysis of the agricultural and water policies currently in force in the area. Secondly, a long term analysis foresees the effects of the future policies along the time span set by the RBA to accomplish the recovery of the WLM aquifer as established in the Upper Guadiana plans (SPUG).

2. Methodological framework: modeling integration

The methodology developed to undertake this analysis is shown in figure 1 and comprises three main parts, namely, the baseline analysis, the economic model and the hydrology component

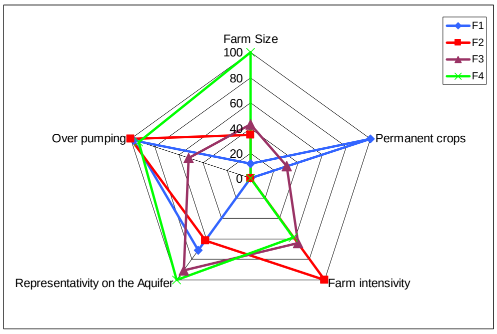
Figure 1. Methodological scheme.



2.1. Baseline analysis

The baseline analysis includes (i) the elaboration of a knowledge-base supported by an ample field work and stakeholder consultation carried out in 2005, 2006 and 2007 (to farmers, irrigation community representatives, technical experts, river basin managers, regional government officials, environmental NGO's, farmers unions, private law firms). (ii) The selection of a set of four statistically-based representative farms that characterize the variety of production systems and farms types in the area. These representative farms correspond to the Irrigation Community of Daimiel that covers around 20,000 ha of irrigated lands and has 1,450 affiliated members. Situated in the western part of the La Mancha aquifer region, the municipality of Daimiel gives its name also to the nearby wetlands of the National Park 'Tablas de Daimiel'.

Figure 2. Farm types' profiles



The structural characteristics of the representative farms are shown in Table 4 and Figure 2 depicts the variety of farm profiles based on other complementary indicators, such as cropping diversity, over-pumping rates (with respect to the established quotas) and farming intensity (measured by the types of crops grown).

Table 4. Farm typology for the Irrigation Community of Daimiel in the region of Castilla-La Mancha

	F-1	**F-2**	**F-3**	**F-4**
Area (ha)	8	24	30	70
Soil quality	low	high	medium	medium and low
Cropping pattern	Vine (100%)	Winter Cereals (30%) Maize (5%) Horticulture (30%) Melon (20%) Set-aside (15%)	Winter Cereals (25%) Maize (5%) Melon (25%) Vine (30%) Set-Aside (15%)	Winter Cereals (58%) Maize (2%) Hortic. & Melon (30%) Set-Aside (10%)
Coverage (% of area)	22	19	28	31

Source: Field work analysis (2006) updated from Sumpsi et al. (1998) (crop distributions are approximate)

2.2. Agro-economic analysis

To analyze the impact of the joint application of water polices and agricultural policies in irrigated agriculture of the area of study we have developed an ***agro-economic model*** that describes the behavior of the farmers confronted with water conservation policies and agricultural policies.

Following previous work by the authors (Varela-Ortega *et al.*, 2006b), the model is a farm-based non-linear single-period mathematical programming model (MPM) of constrained optimization that incorporates new risk parameters and a more ample empirical scope. The model maximizes a utility function (U) subject to technical, economic and policy constraints. It can be summarized as follows:

Objective function

$$MaxU = Z - \phi \cdot \sigma \tag{1}$$

where U is the expected utility, Z the average net income, ϕ the risk aversion coefficient and σ the standard deviation of the income distribution. Average farm income is calculated as follows:

$$Z = \sum_c \sum_k \sum_r gm_{c,k,r} \cdot X_{c,k,r} + \left[\sum_c \sum_k \sum_r subs_{c,r} \cdot X_{c,k,r} \cdot coup + sfp \right] \cdot mdu - foc \cdot \sum_p fla_p - hlp \cdot \sum_p hl_p - wac \cdot wc - canon \cdot sirrg - nwell \cdot twell \tag{2}$$

where $X_{c,k,r,f}$ are the decision-making variables representing the growing area by crop type (c) soil type (k), irrigation technique (r) and farm type (f); $gm_{c,k,r}$: gross margin; $subs_{c,r}$: CAP support; *coup*: coupling rate; *spf*: single farm payment. *mdu*: modulation rate; *.foc*: family labor opportunity cost; fla_p: family labor availability; *hlp*: hired labor wage. hl_p: hired labor.

The standard deviation is generated by a set of states of nature defined by climate variability (crop yields) and market variability (crop prices) as follows:

$$\sigma = \left[\left(\sum_{sn} \sum_{sm} Z_{sn,sm} - Z \right)^2 / N \right]^{1/2} \tag{3}$$

where $Z_{sn,sm}$: random income as a function of the state of market prices (sm) and of the state of nature (sn); N: combination of the different states (N=100).

Land constraints

$$\sum_c \sum_k \sum_r X_{c,k,r} \leq surf_k \tag{4}$$

$$\sum_c \sum_k \sum_{ri} X_{c,k,r} \leq sirrg \tag{5}$$

where *surf*: available land; *sirrg*: potential irrigated surface.

Labor constraints

$$\sum_c \sum_k \sum_r lr_{c,r,p} \cdot X_{c,k,r} \leq fla_p + hl_p \tag{6}$$

where $lr_{c,r,p}$ is crop labor requirements; fla_p family labor availability; hl_p hired labor.

Water availability constraints

$$\sum_c \sum_k \sum_r wneed_{c,k} \cdot X_{c,k,r} \leq wava \cdot sirrg \cdot h_r \tag{7}$$

Where $wneed_{c,k}$: crop water needs; *wava*: water availability; h_r: technical efficiency coefficient.

Other policy relevant constraints: cropping permits, set side requirements, etc.

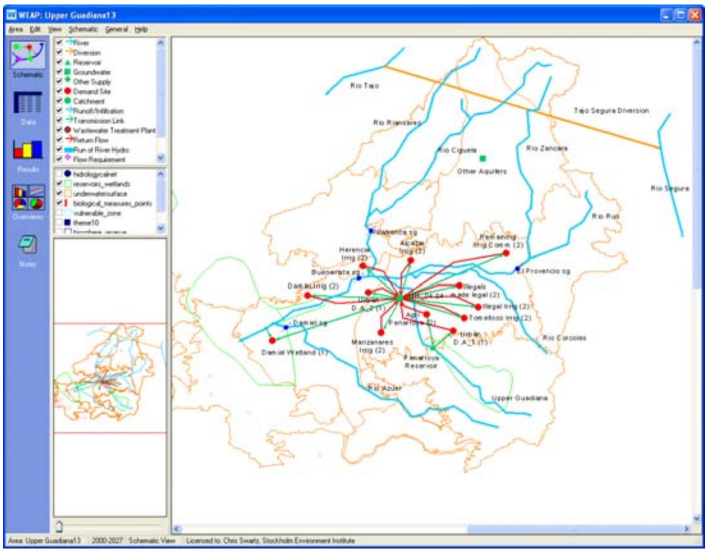
The problem-solving instrument used is GAMS (General Algebraic Modeling System). The technical coefficients and parameters of the model were obtained from the fieldwork. The model was duly calibrated and validated, using the risk aversion coefficient as calibration parameter and the comparative data on crop distribution, land and labor parameters in the study area.

The policy scenarios that have been simulated include: (i) two agricultural policy scenarios, the current CAP regime with a partial decoupling of subsidies (75% for Spain) for the short run analysis and a full decoupling scheme for the long term analysis. (ii) the Agro-environmental programs correspondent to the 2003 scheme (50% and 100% volume reductions, see table 2) in force up to 2007, for the short term analysis. (iii) the Water Abstraction Plan (WAP) currently applied in the area both for the short term and long term analysis. (iv) the Special Plan for the Upper Guadiana (SPUG) as foreseen by the RBA along a time span towards 2027.

2.3. Hydrology analysis

To quantify the impacts to aquifer storage in the basin under the different agricultural policies described above, the scenario-driven water resources modeling platform WEAP was implemented. The WEAP modeling platform allows integration of pertinent demand and supply-based information together with hydrologic simulation capabilities to facilitate an integrative analysis of a user-defined range of issues and uncertainties, including those related to climate, watershed conditions, anticipated demand, ecosystem needs, regulatory drivers, operational objectives, and infrastructure. The user-defined demand structure and water allocation priority and supply preference designations drive the linear programming allocation algorithm for the water balance, allowing robust analysis of water allocation ‘trade offs’ within possible future hydrologic and ecologic regimes developed in a scenario framework (SEI, 2008). Following previous work by the authors (Varela-Ortega *et al.*, 2006a), a representation of the basin, including all pertinent demand and supply elements and their inter-relations, was constructed in WEAP using its graphical user interface (Figure 3).

Figure 3. WEAP representation of the Upper Guadiana basin.



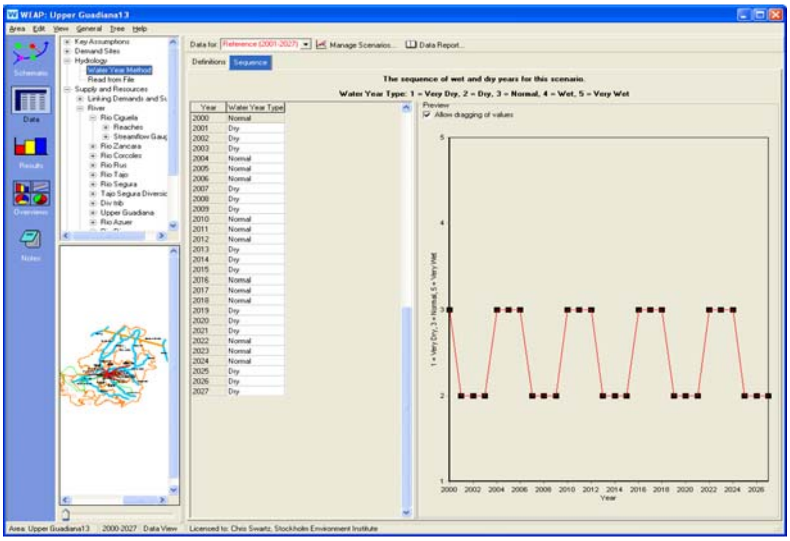
Elements include major rivers (blue lines), major aquifers (green squares), and two domestic urban water and seven agricultural water demand nodes (red circles). In the reference condition, six of the seven agricultural demand nodes and one of the urban domestic nodes (D.A_2) derive irrigation water from groundwater (UH_04.04); one agricultural demand node (Penarroya) and one urban domestic node (D.A_1) derive irrigation water from a local reservoir (green triangle) on the Upper Guadiana river. Green arrows represent transmission links between demand nodes and their preferred water supply sources. Demand nodes return unconsumed water to groundwater (infiltration; via red arrow links) in this construct.

Behind each model elements lies the associated user-defined data that drives the water balance calculations, such as population, agricultural area, water use rates, groundwater recharge, streamflow, and reservoir capacity. Time dependencies of variables or other relational dependencies between variables are defined here also. For example, in this study, the future purchase of water use rights is manifest through reductions in the area of each regional agricultural demand node with time. Remember that the policies analyzed herein designate the use of a portion of these purchased water rights to be granted in turn to illegal farmers to 'convert' them to legal status. As such, we have added the additional agricultural demand node ('Illegals made Legal'; Figure 3) that becomes active in the scenario year 2007, and which grows in area during the period 2007-2009 to accommodate the water rights granted.

On the supply side, streamflow and groundwater recharge for the starting year of the analysis (2002) were derived from existing data and estimates. For river headflow, the mean value of monthly headflow over the period 1946-1997 was used, and for groundwater recharge, an estimate of current recharge (comprising contributions from rainfall, riverbed infiltration, agricultural and domestic runoff infiltration, and lateral inflows/outflows) was obtained from the Guadiana River Basin Authority.

Future expectations for groundwater recharge and streamflow are important variables to consider in this analysis of the ability of certain agricultural policies to mitigate groundwater decline in the basin. While output derived from any type of climate model can be input directly into WEAP to represent expected future hydrologic conditions, this study chose to represent future climate conditions with a simpler construct. For future climate conditions, we derived two sequences. For the first climate sequence, year 2000 streamflow and the portion of groundwater recharge due to precipitation, lateral inflows/outflows, and riverbed infiltration were each decreased by 0.45% annually to represent an 11% cumulative decrease in rainfall expected by 2027. For the second climate sequence, we analyzed the river headflow dataset (1946-1997) to obtain 90th, 75th, 25th, and 10th percentile values and normalized them by the mean (50th percentile) value. The resulting factors were used to define very dry (10th percentile; 0.085), dry (25th percentile; 0.28), wet (75th percentile; 2.50) and very wet (90th percentile; 5.09) conditions relative to normal (50th percentile) – these factors could then be applied to the starting year (2000) river headflow and groundwater recharge to generate a simple future climatic sequence with user-defined interannual variability. We used an alternating three year 'dry' and three year 'normal' sequence (Figure 4) as the second climate expectation to simulate the impact of periodic, extended drought conditions.

Figure 4. A simple climate sequence chosen for analysis.



3. Results and discussion

The simulation results of the economic model are summarized in Tables 5 and 6 below, showing respectively, the short term and the long term analyses. In the short term analysis the CAP scenario corresponds to the partial decoupling scheme currently in force. For the long term analysis we have assumed that the CAP programs will evolve into a full decoupling structure. Water policies have been analyzed for both types of agricultural policy settings selecting the current programs in force in each period.

Table 5. Results of policy analysis in the Partial Decoupling Scenario (PD) (short term analysis)

AGGREGATE RESULTS	POLICY OPTION						
	Ref. policy (PD)	WAP[a]	AEP[b]		Purchase of water rights		
			AEP_1= 50% Red.	AEP_2= 100% Red.	P_1= 3.000 €/ha	P_2= 6.000 €/ha	P_3= 10.000 €/ha
Farm Income							
Total (€/ha)	917	769	769	691	421	641	936
%	100	84	84	75	46	70	102
Water Consumption							
Total (m3/ha)	3304	2495	1247	0	0	0	0
%	100	75	38	0	0	0	0
Public Expenditure							
Total (€/ha)	127	130	328	612	343	563	858
%	100	103	258	482	270	443	675
Water Shadow Price							
Total (€/m3)	0,006	0,061	0,082	0,973	0,973	0,973	0,973
Water Costs							
Total (€/ha)	202	153	78	0	0	0	0
%	100	76	39	0	0	0	0
Water Costs							
Total (€/m3)	0,061	0,061	0,063	0	0	0	0
Water Productivity							
Total (€/m3)	0,307	0,308	0,611	0	0	0	0
Inc. compensation AEP							
Total (€/m3)	-	-	0,159	0,197	-	-	-
Crop Distribution							
Rainfed (%)	0	19	52	100	100	100	100
Irrigated (%)	100	81	48	0	0	0	0

Notes: "a" Water Abstraction Plan, "b" Agri-environmental Programs.

Table 6. Results of policy analysis in the Full Decoupling Scenario (FD) (long term analysis)

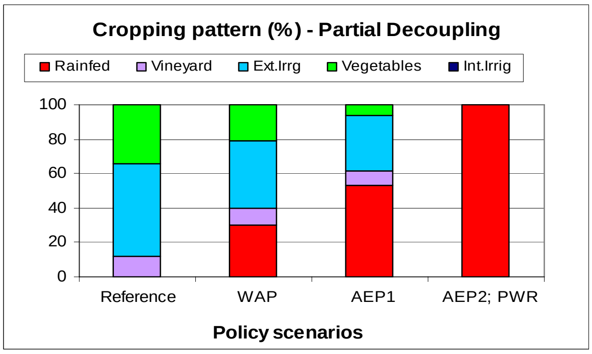
AGGREGATE RESULTS	POLICY OPTION				
	Ref. policy (FD)	WAP[a]	Purchase of water rights		
			P_1= 3.000 €/ha	P_2= 6.000 €/ha	P_3= 10.000 €/ha
Farm Income					
Total (€/ha)	958	921	434	655	949
%	100	96	45	68	99
Water Consumption					
Total (m3/ha)	3261	2495	0	0	0
%	100	76	0	0	0
Public Expenditure					
Total (€/ha)	130	130	343	563	858
%	100	100	263	432	657
Water Shadow Price					
Total (€/m3)	0,004	0,067	0,973	0,973	0,973
Water Costs					
Total (€/ha)	199	153	0	0	0
%	100	77	0	0	0
Water Costs					
Total (€/m3)	0,061	0,061	0	0	0
Water Productivity					
Total (€/m3)	0,321	0,368	0	0	0
Crop Distribution					
Rainfed (%)	0	41	100	100	100
Irrigated (%)	100	59	0	0	0

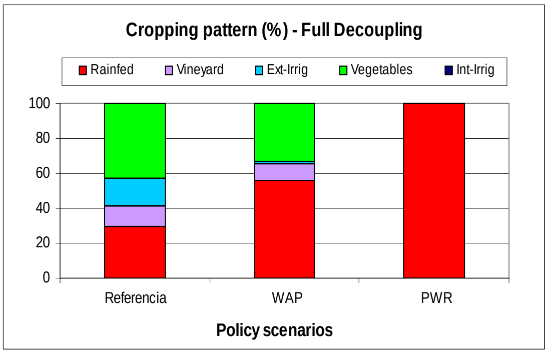
Notes: “a” Water Abstraction Plan.

3.1. The agronomy: Water consumption and cropping patterns

In the short term partial decoupling scenario, water use reductions to reach the aquifer’s recharge target are met for the WAP and the AEP programs (from over 3300 cm per ha in the reference situation to 2495 cm per ha and 1247 cm per ha respectively). This level is also attained in the longer term analysis, although AEP programs disappear and in its place, the SPUG is applied for three levels of purchase water rates (3,000, 6,000 and 10,000 € per ha, as established in the program). This result does not mean that the recharge target will be met in the overall sub-basin, as evidenced in the hydrology analysis (see next section). Water consumption results form the cropping patterns chosen by the farmers in each scenario (see figure 5). We can see that farming extensification takes place when the WAP is enforced, that is, rain fed farming appears and intensive irrigation crops, such as maize, are sharply reduced towards less water demanding crops, such as winter cereals (wheat and barley) and intensive vegetable productions are also diminished. This trend is reinforced along the AEP programs. In the full decoupling scheme of the long term analysis, extensification starts even in the reference situation, and this trend is reinforced in the more water-scarce WAP, evidencing a clear synergy of CAP programs with water conservation targets. In fact, full decoupling shows a polarization of cropping trends. Cereals are clearly penalized in the FD scenario and are being substituted by, on the one side, water-intensive horticulture crops and by rainfed crops on the other side.

Figure 5. Crop distribution by policy scenarios in partial and full decoupling



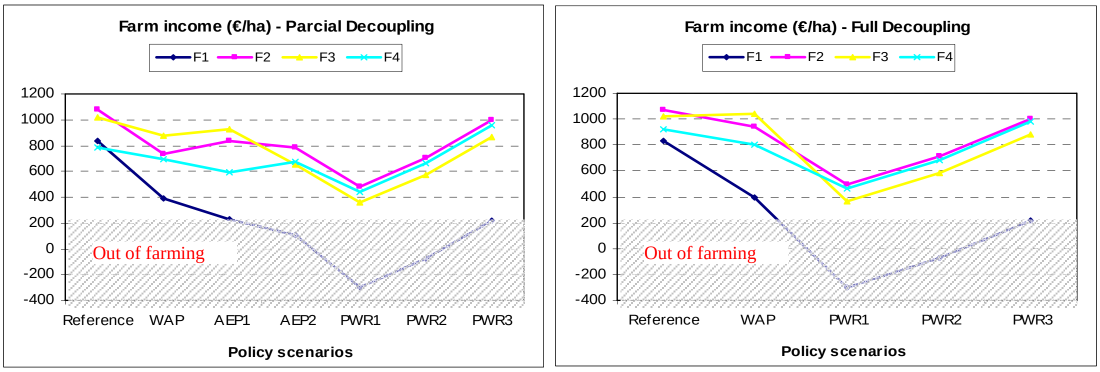


3.2 Farm income and purchase of water rights

In the aggregate farm type (tables 5 and 6) farm income is reduced by 20% when the WAP quotas are applied in the short term partial decoupling scenario. This tendency is mitigated in the long term FD, evidencing that a full decoupled subsidy scheme acts as a risk shelter for farming irrigated agriculture. However, when farmers sell their water rights within the SPUG program, both scenarios produce equivalent farm income reductions and the original level of income gain is only attained when water rights are compensated to the highest price rate of 10,000 € per ha (income reaches 102 and 99 per cent with respect to the reference baseline respectively in the PD and FD scenario).

When comparing the different types of farms (Figure 6), results show that farm income variations are less pronounced in the FD scenario. Conversely, income is reduced less drastically as water availability diminishes from the reference situation to the WAP quota system when subsidies are decoupled from production. The new decoupled program being less risky for farming than the precedent coupled program.

Figure 6. Farm income variations by policy program and farm type



However, willingness to sell the entitled water rights varies across farm types and irrigators' attitudes and it is dependent on the cropping pattern chosen in each scenario. Prices offered by the RBA in the Water rights exchange center, range from 3000-10000 € per ha for herbaceous annual crops and form 3000-6000 € per ha for permanent crops (vineyards). Based on these data, Table 7 shows the maximum, minimum and average revenue collected by the farmers when they sell their water rights. An irrigator will be willing to sell his water rights when the price perceived will compensate his lost income when passing from irrigation farming (in the WAP situation) to rain fed farming. As water rights are sold on a permanent basis, the annual compensation payment is calculated by the annuity of the perceived income flow over a period of 20 years along which water rights will hold (interest rate is set at a real rate of 4%). Table 8 shows the willingness to pay of the different types of farms. We can see that only F2 and F4 farm types will be willing to sell their water rights if water prices reach the upper level.

Table 7. Farmers' willingness to sell water rights.

Sale price of water rights (€/ha)	Representative farms type				
	F1	F2	F3	F4	Average
Maximum	6000	10000	8800	10000	9528
Minimum	3000	3000	3000	3000	3000
Average	4500	6500	5900	6500	6264

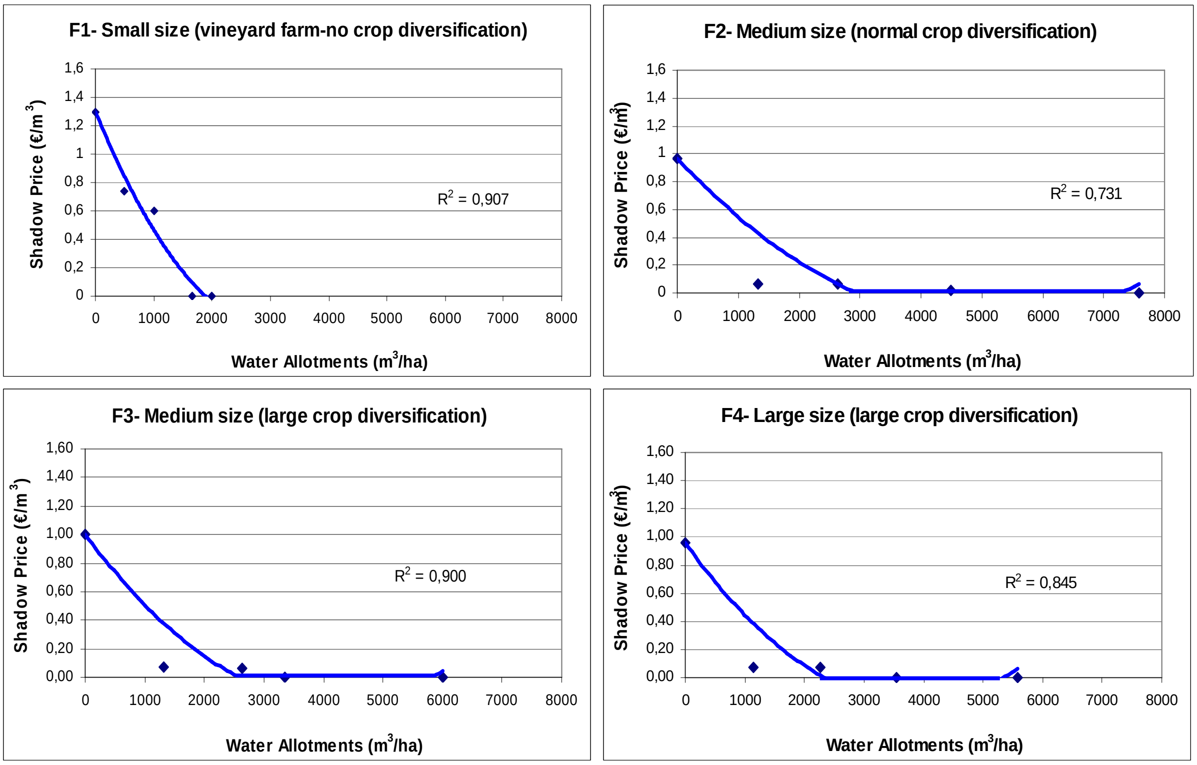
Table 8. Selling of water rights faces different water price levels.

Representative farms type	Updated income losses (€/ha)		Sale of water rights		
	PD	FD	P_1= 3.000 €/ha	P_2= 6.000 €/ha	P_3= 10.000 €/ha
F1	16.601	16.601	NO	NO	NO
F2	8.545	12.312	NO	NO	YES (PD)
F3	13.575	16.353	NO	NO	NO
F4	8.614	10.175	NO	NO	YES (PD)

3.3 Farms' vulnerability and adaptive capacity

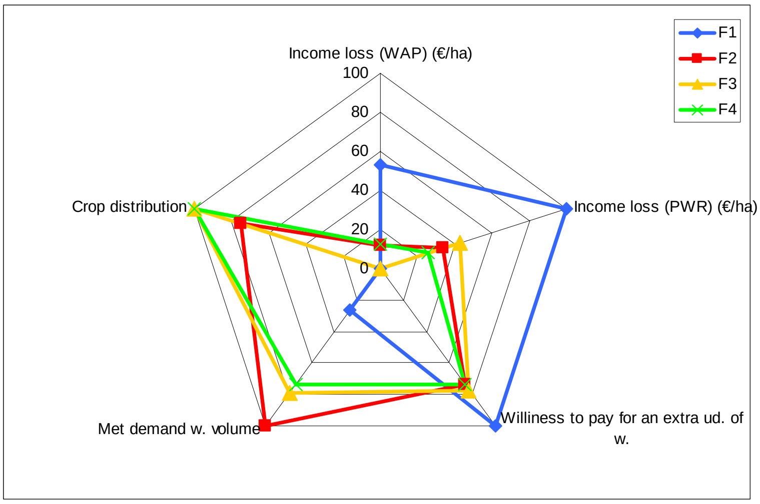
The capacity that farms have to adapt to different levels of water scarcity can be analyzed looking at the water dual values (shadow prices) in the model results (see tables 5 and 6). Water shadow prices of marginal values can be used to assess the impact of water conservation policies and has been discussed extensively in the literature as average values can be ambiguous or misleading (Johansson *et al.*, 2002, Turner *et al.*, 2004, Hanemann 2006, among others). The value of water for farmers is not constant and increases as less water is supplied because farmers are likely to change their crops and technologies in response to water availability. This is shown in the model results. Figure 7 shows the dual values of water for different levels of water availability across farm types obtained in the model simulations. The 'water demand curves' constructed using water shadow prices show that farm types have distinctive adaptive capacity to water availability. Curves show the farms' ability to adjust their cropping patterns, technologies and farming operations. When water shadow price is zero, the farm will be satisfied with the amount of water available and will not be willing to pay for an extra unit of water. We can see that the medium-size farm F3, with diversified annual crops has a high short-term adaptive capacity as it will operate with 6000 m3 per ha, as compared to its less-diversified counterpart F2 that, due also to size limitations, requires a larger volume of water (7500 m3 per ha) . In contrast, the small vineyard farm F1 is highly adapted to lower water volumes (2000 m3 per ha) due to the use of efficient irrigation technologies such as drip irrigation, widely used in vine groves in the area.

Figure 7. Dual values of water across farm types from different levels of water availability



Assessing farms' vulnerability and adaptive capacity is complex and has been discussed extensively in the literature (Downing *et al.*, 2001; Alwang *et al.*, 2001; Downing *et al.*, 2006; ;among others). Although our analysis is still limited, it has been reinforced using a more varied set of indicators (see figure 8). These are income loss when the WAP reduced volumes are applied or the purchase of water rights are established (water price level of 6000 €/ha), the willingness to pay for an extra water volume, the water volume that satisfies water demand in the farms and the cropping mix variation potential of the farms. We can see that farms have different responses to these indicators, showing distinct adaptive capacity to water use limitations. The diversified larger and medium-size farms F4 and F2 respectively are more adapted to water stress conditions. They loose a smaller proportion of farm income when both WAP and water rights are sold, and water demand requirements are met at lower water volumes when compared to the other farm types. This result evidences that economies of scale as well as cropping mix potential play an important role in the adjustment process towards water scarcity in this region.

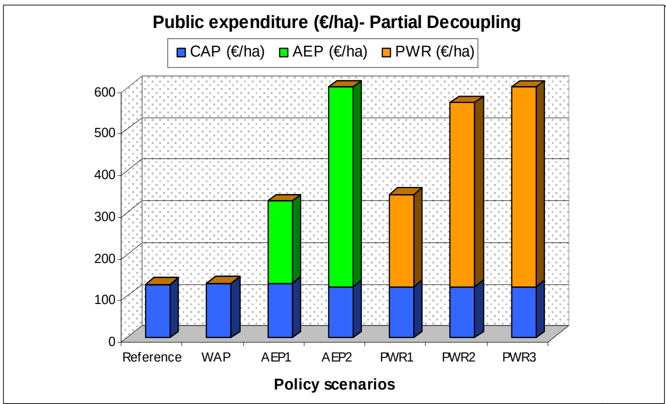
Figure 8. Farms' profiles (Vulnerability analysis)

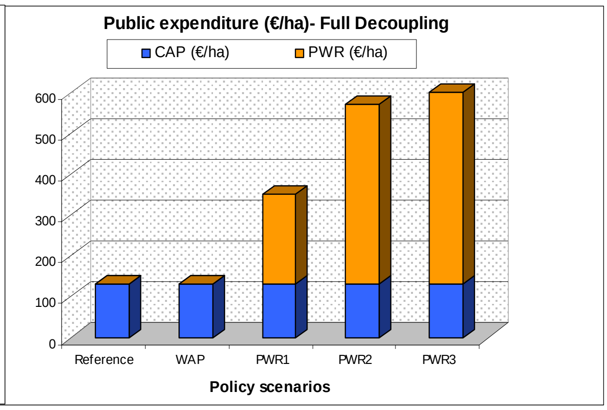


3.4 Public expenditure and cost-effectiveness

The role of the Agri-environmental programs for conserving water resources is limited as these programs require large public funds. Comparing with the reference baseline scenario, public expenditure is more than two fold and four fold respectively in the AEP 50% and 100% schemes (258% and 482%). Thus cost-effectiveness of these programs is low. Public expenditure is equivalent in the purchase of water rights program (SPUG) for the medium price range level but water is reduced further in this program, especially in the long term perspective (see Figure 9).

Figure 9. Public expenditure (€/ha) by policy program.



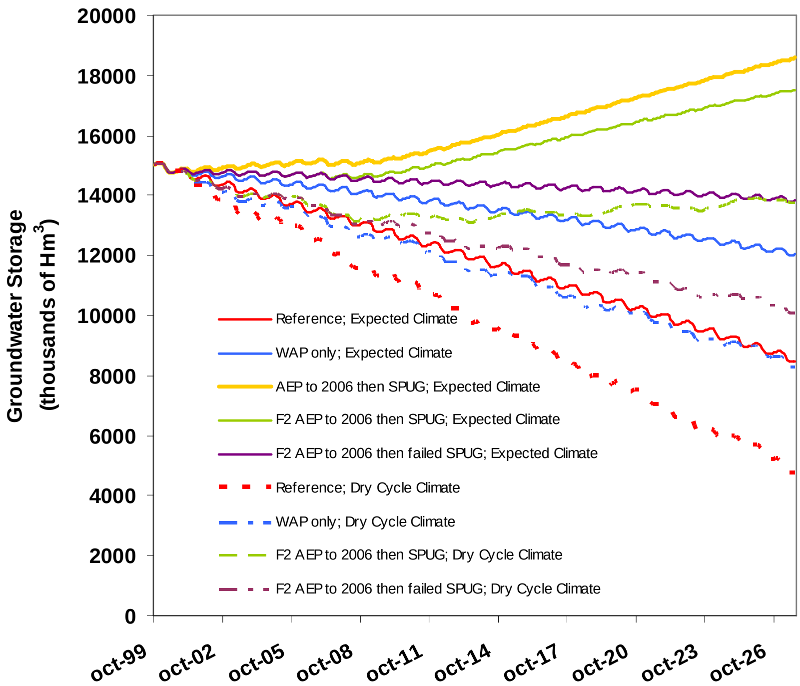


3.5 Meeting environmental objectives: aquifer's recharge

Impacts to groundwater storage through 2027 are demonstrated in the results of the WEAP simulations (Figure 10). Under the first climate condition, in which streamflow and natural groundwater recharge decrease by 11% cumulatively over the period, groundwater storage would decrease by approximately 5 bcm beyond current levels if no corrective action were taken ('Reference' in Figure 10), i.e., irrigators use water at rates existing before 2001. If only the WAP policy ('WAP only' in Figure 10) had been implemented in 2001 and continued beyond 2006, storage would fall another 2.3 bcm by 2027. In contrast, a 2.8 bcm increase in storage relative to the 2006 volume is anticipated if one assumes all farm types fully participate in SPUG policy conditions starting in 2007 following a period (2001-2006) in which only F2 farms opted to comply with AEP reductions (at 100% reduction; 'F2 AEP to 2006 then SPUG; Figure 10). If no farms agree to sell water rights under the SPUG policy implementation, groundwater storage roughly maintains its present volume, losing approximately 900 mcm ('F2 AEP to 2006 then failed SPUG'; Figure 10).

The situation could be much different if future climate is characterized by cyclic droughts, rather than the gradual decrease in rainfall, streamflow, and groundwater recharge represented by the 'Reference' climate. Under the 'Dry Cycle' climate, even if all farm types participate fully in SPUG starting in 2007, groundwater storage is simulated to increase by only 76 mcm relative to the 2006 volume ('F2 AEP to 2006 then SPUG, Dry Cycle climate; Figure 10). If the SPUG policy fails, with no farms selling water rights, aquifer storage decreases by 3.6 bcm through 2027 - a situation worse than if only the WAP policy had been continued through 2027 under a 'Reference' climate.

Figure 10. Potential trends in groundwater storage in the Guadiana basin.



For those agriculture areas that depend on surface water for irrigation, specifically in the Penarroya area of the basin where irrigation water is obtained from the Penarroya reservoir on the Upper Guadiana river (see Figure 3), the impact of the 'Dry Cycle' climate conditions are even more dramatic. Penarroya agriculture is simulated to experience 20 to 40 mcm of unmet demand during the months of April through July in the each of the dry years in the Dry Cycle climate sequence. This volume that can not be met by the reservoir storage under this climate scenario represents approximately 70% of its total water requirement during each of those months.

4. Conclusions

- The agro-economic and hydrology modeling integration presents an innovative analysis that provides a useful tool for assessing water and agricultural policy-relevant scenarios in water stressed areas. The baseline micro-scale vision is then aggregated to the basin-level by means of a hydrology model (WEAP, SEI 2006) coupled to the economic model by reproducing the same policy scenarios. Differential outcomes are predicted across farm types and this methodology shows the extension of IWRM into the core elements of AWRM.

- We can conclude from the results of the economic-hydrologic integrated analysis that, in general, short term water conservation policies that are being implemented in the Upper Guadiana basin, can contribute to reduce water consumption in the farms, but will not be able to achieve, in the aggregate, the recuperation of the Western La Mancha aquifer. The desired target of the aquifer replenishing will be met only when the long term full application of the newly approved measures for reducing water abstractions will be enforced (buying water rights and closing up unlicensed wells). However, the recovery objective will be difficult to meet in case of droughts.
- In general, water conservation polices that apply a strict quota system can achieve water use reductions at low public costs. However, these policies are likely to be opposed strongly by the farmers, and would entail high enforcement costs to the public authorities. Increasing the direct participation of stakeholders and stronger involvement in the decisions as well as social learning activities are strongly needed for the acceptance of this type of policies.
- Water conservation polices that include a quota system and an income compensation scheme (such as the agri-environmental programs), can achieve the programmed water conservation target provided that a large proportion of farmers are willing to participate in the program. These policy programs generally have a higher social acceptance but are costly policies and cost-effectiveness is low. Such programs conflict with the recently adopted EU Water Framework Directive that requires a cost-effective evaluation of all program measures (Directive 2000/60/EC).
- A coordinated and integrated design and implementation of agricultural polices and water polices is a key element for ensuring the dual objective of conserving water resources and maintain farm-based livelihoods at tolerable social costs. This will be best attained in an integrated transparent stakeholder-participatory manner, avoiding contradictions, finding synergies and reinforcing common objectives. This is the challenge facing the Spanish regional administration in charge of the application of both national and EU water policies in the area that we have studied. The requirements of the WFD to reach 'a good ecological status of all water bodies' in the EU with 'public transparency and participation' is providing incentives to the regional and national administrations to better enforce the water conservation policies. The new rural and social development programs that are being launched in this area are designed to diminish economic and social burden. The design and enforcement of well-balanced polices is one of the major tasks of policy makers for achieving successful water management policies.

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