WATER MANAGEMENT POLICIES TO IMPROVE SURFACE IRRIGATION

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Abstract

An economic and environmental analysis of various policy measures is undertaken in this paper. A bio economic model of agricultural activities in the Bardenas irrigation area of the Ebro basin in Spain is constructed. The model includes production function of crops, estimated with EPIC crop growth package. The model results show the effects on crop yields, water and nitrogen demand, and on control nitrogen pollution when the different measures are considered. These measures are evaluated by their cost efficiency. A standard in water applied by 25 per cent is the best measure to abate nitrogen pollution, following by the quantitative limit on applied fertilizer and nitrogen price increases. The limit on water applied is an appropriate measure to avoid the overuse of water resources, and this option would require the establishment limits on concession to the irrigation district associations, measure the flow and control the water applied by farmers.

Key words: bioeconomic model, measure of water manegement, cost efficiency of measure

1. Introduction

In Spain, water economy is in a situation that it is similar to a “mature phase” characterises by a low offer elasticity of storage water on long time, deterioration of storage and distribution systems that is necessary to repair and renew [19]. Because of the large and increasing water irrigation demand the conflicts among user groups and regional governments is very strong. The negative ambiental externalities have been continuously increasing due to over-explotation of water resource, pollution by fertilizers and pesticides, and the salinity. There is a large social replication to an increasing subsidised water use.

The increasing social sensibility about water use and European regulations on water resources will suppose great revisions in the management of these resources. In Spain, the institutional change in the water management is consequence of three normative processes that are still progressing: Water Law Reform in 1999 developed by 2003’s regulation, the National Hydrological Plan and National Irrigation Plan, and European Union’s Water Framework Directive.

The Basin Hydrological Plans forecast an increasing water irrigation demand by horizon 2015 (Table 1), although these provisions are based in extrapolation of tendency and not response to economic concept of demand. Reliable information on urban, industrial and water irrigation demands is scarce, and it is impossible to realize a precise analysis. As well, it has to account the structural adjustments that can happen in the institutional organization of sector, environmental and agricultural policies, and the trade liberalization.

On the other hand, the economic-finance regulation of water law in 1985 is not favorable for an efficient use of water resources. The regulation is based in the rationing system: the water demand for agriculture use is very high because of the rationing system applied to water resource. Low prices generate a large excess demand that is covered through administrative allocation. The present system of concession allows the farmer to possess water quantity high subsided. In Spain, the large storage infrastructure managed by hydrological confederations suppose substantial supports by government, between 90 and 100 percent of water production cost, while the cost recuperation is very low, between 15 and 20 percent [11].

Table 1. Water demand as Basin Hydrological Plans by sectors (hm^3, 1995-2015)

Sectors	Demand year 1995 (1)	year 2005 (2)	year 2015 (3)	Increasing 1995-2015 (4 = 3-1)	in % (5 = 4/1)
Urban	4.667	5.347	6.313	1.646	35,3
Industrial	1.647	1.917	2.063	416	25,2
Agricultural	24.094	27.123*	30.704	6.610	27,4
Total **	**30.408**	**34.387**	**39.080**	**8.672**	**28,5**

Source: [14]. * The National Irrigation Plan estimates the water irrigation demand on 25.022 hm^3 by 2008 [13]. ** the refrigeration and environmental is not included

In this context, the Water Law Reform suggests the introduction of water saving measures, such as water use measure and establishment quantity standards, accompanies by initiative and penalisation systems in order to reduce the critical problems of overuse and degradation of water resource.

2. Material and Methods

The study area is “Comarca de Cinca Villas” located in the irrigation area of Bardenas, in the Zaragoza province. The area under study encloses twenty eight villages, and has an extension of 65.000 ha. The main crops in the irrigation area are corn and alfalfa (50 % of cultivated surface), winter cereals (barley and wheat), although vegetable crops (tomato, pepper) are cultivated in some part of the area (3 % of cultivated surface).

The water resources origin is the Yesa dam with 470 hm^3 of capacity, which regulates the Aragón river water, through the Bardenas channel. There is a vapor transpiration deficit from May to September, and therefore irrigation is essential for agricultural production [7]. The distribution systems have a conveyance capacity below well peak demand.

The Hydrological Plan of Ebro watershed indicates that the water maximum quantity for the district is 9.130 m^3/ha, and this quantity is reduced significantly in dryer years [5]. The traditional irrigation technology is the common irrigation system (92 %) although sprinkler and drip irrigation has been introduced in some areas (8 %). The surface of modern irrigation systems, sprinkler and drip, is lower than the national average [8]. The water volume used measure by user is not controlled, and the water price is based on the irrigation acreage and not on water use.

2.1. Crop growth model

The EPIC crop growth package[1] is applied in detail in the irrigation district “Comunidad de Regantes V” [15]. This area is the largest irrigation extension in Bardenas, and has a total of 17.658 ha, of which 90 percent (15.498 ha) is irrigated. The physical and socio-economic characteristic of “Comunidad de Regantes V” is described by author [21].

The yield response is estimated using the EPIC crop growth package. As well, the EPIC package is used to estimate the percolation and nitrogen leaching. The EPIC incorporates local information on climate, soils, tillage operations, and irrigation systems of crop activities, and it is applied in detail in the irrigation district “Comunidad de Regante V”. It is considered the main soil group named “plataformas” that occupies 80 percent of area. The crops considered are corn, barley, wheat, alfalfa, sunflower, rice, tomato and pepper. These crops occupy the large acreage in the area (85 %).

The EPIC calibration has been realized with help of experts of Genetic Department of Aula Dei’s Experimental Station (CSIC), and Blackland Research Station (Temple-Texas).

[1] The EPIC crop growth package and its applications are exposed in details [21].

The yield obtained from the EPIC package have been validated with surveys to farmers in the irrigation district, information of Agriculture Ministry and Aragon Government, and with experimental information of Aragon's Agrarian Experimental Network. The percolation and nitrogen leaching have been validated with information on water and nitrogen losses in the irrigation district "Comunidad de Regantes V" [7].

2.2. Bioeconomic model

The bio economic model is build with crop response function to water and nitrogen. The yield function used is the quadratic specification, since it is the common specification in the literature:[2]

$$y_j = f(w,n) = \beta_0 + \beta_1 \cdot \mathrm{w} + \beta_2 \cdot \mathrm{w}^2 + \beta_3 \cdot n + \beta_4 \cdot n^2 + \beta_5 \cdot \mathrm{w} \cdot n \qquad [a]$$

where y_j is yield of crop in metric tons per hectare (Tm/ha), w is irrigation water applied in m^3/ha and n is active nitrogen applied in kg/ha. The yield function for corn, barley, wheat, alfalfa, rice and tomato has been estimated. The yield function for pepper is not possible to estimate because it presents problems of convergence during estimation. The functions have been estimated by Ordinary Quadratic Minimum (MQO), using SHAZAM econometric package.

The optimization problem is no lineal and objective function maximizes crop net revenue. The problem is defined by the expression:

$$\underset{j,\mathrm{w}_j,n_j}{Max} \sum_{j=1}^{8} (p_{yj} \cdot y_j - p_{\mathrm{w}} \cdot \mathrm{w}_j - p_n \cdot n_j - c_j + s_j) \cdot x_j \qquad [b]$$

where y_j is crop yield (Tm/ha), p_{yj} is crop price, p_w is water price (€/m^3), p_n is active nitrogen price (€/kg), c_j denotes crop costs (€) other than water and nitrogen costs (cost include direct and indirect expenditure, seeds, herbicides, machinery, labour, and amortizations), s_j is direct subsidies (€/ha), and x_j crop acreage (ha). Water irrigation and nitrogen fertilizer costs are shown separately in the objective function. The crop net revenue is calculated from crop production cost obtained from information of Agriculture Ministry [12].

The restraints of model incorporate constraints representing resource availability (soil, water and labour), sit-aside requirements, agronomic (succession and frequency) and aggregation conditions[3]. The model includes two soil restrictions, for cereals and vegetables crop respectively. The restrictions are defined by expression:

$$\sum x_j \le b_{os} \qquad [c]$$

where x_j is the crop acreage (ha) as type of occupation (cereals, vegetables), b_{os} represents the soil availability for each type of occupation (ha).

The water restrictions are defined by expression [d]. The model includes twelve water consumption restrictions that represent annual water requirements for each crop.

$$\sum \mathrm{w}_{\mathrm{jm}} \cdot x_j \le b_{\mathrm{wm}}, \ \sum b_{\mathrm{wm}} = W \qquad [d]$$

where w_{jm} is the quantity of crop applied water in the month m (m^3/ha), x_j represent the crop acreage (ha), b_{wm} is the water availability in the month m (m^3/ha) and W is water availability annual or water use annual (m^3/ha/year).

The expression [e] is the labour restriction. The labour data of each crop for the irrigation area "Cinca Villas" are obtained from Agrarian Extension Service of Aragon. The model includes twelve restrictions that correspond to labour requirement for month and crop.

$$\sum o_{j_m} \cdot x_j \le b_{om}, \ \sum b_{om} = B \qquad [e]$$

where o_{jm} is labour requirement for each activity x_j in the month m (hours/ha), b_{om} represent labour availability in the month m (hours/ha), and B is the labour availability annual (hours/ha/year).

The constraint [f] includes the Common Agriculture Policy (CAP) sit-aside requirements. The sit-aside percentage fixed changes every year, and for year 1999 is 10 percent. This percentage is not applied for alfalfa, rice and vegetables. The net revenue of sit-

[2] The common crop response functions used in agricultural economics are described by author [21].

[3] The constraints of model are described by author [21].

aside activity is equal to subsidy, and the model includes one sit-aside restriction.

$$x_r \leq \sum x_j \cdot P \qquad [f]$$

where x_r is the acreage sit-aside, and P is the percentage fixed by CAP.

Constraint [g] and [h] are agronomic restrictions in the area, frequency and succession crop equations that affect crop acreage. The equation [g] represents crop succession requirement, and the model includes seven restrictions.

$$x_j \leq \sum_{k=1}^{8} x_k \text{ , } j \neq k, j, k = 1,\ldots,8 \qquad [g]$$

where x_j is crop acreage (ha), and x_k is previous crop acreage (ha).

The equation [h] is frequency requirement and defines the relation between the time that crop is in the plot and the break time of soil. The model includes seven restrictions.

$$x_j \leq \frac{t_p}{t_p + t_d} \cdot b_{os} \qquad [h]$$

where x_j is crop acreage (ha), t_p represents the time on the plot, t_d is rest time, and b_{os} is availability soil.

In this work, is examined the aggregation issue that is an important question to validate the results. The aggregation permit to convert results obtained by simulation for one hectare to all the area or region that includes large surface and different plot. The model in this study is a regional model and the aggregation issue is solved by the procedure proposed by several authors [9], [16], [17]. The equation [i] is the aggregation constraint and achieves that crop production solution to be a convex combination of observed production. This restriction is introduced such as the acreage for each crop j is a convex lineal combination of observed acreage. The crop acreage is obtained from Agricultural Department of Aragon 1-T database for 1995-2001 [6]. The model includes ten aggregation constraints.

$$x_j = \sum_{t=1}^{n} \alpha_t \cdot x_{j_t} \text{, being } \sum_{k=1}^{8} \alpha_k = 1 \text{, } 0 < \alpha_j \leq 1 \quad [i]$$

where x_j is acreage crop in optimum, x_{jt} represent the areage crop in the period t, and α_j is the aggregation parameter.

The optimization problem is used to simulate different measures of water management of surface irrigation and analyse their cost efficiency to abate the pollution by percolation and leaching. The bioeconomic model is written in GAMS and solved using the CONOPT II solver [3]. In the simulation is compared the baseline scenario or actual situation with limit in irrigation water applied and setting a standard on fertilizer nitrogen. The variables to measure the scenario effects are production, inputs use, net revenue and environmental impact by percolation and nitrogen leaching.

3. Results and discussion

The table 2 shows the yield function estimated[4] for each crop, which are introduced in the optimization problem. The table 3 shows for each crop and using the yield function estimated, the actual situation of yield, inputs use, net revenue, percolation and leaching. The crops more profitable are tomato, pepper, corn, rice and alfalfa. Under surface irrigation there is an overuse of water and nitrogen that generate high losses by percolation and leaching. The overuse of inputs, water and nitrogen, is indicated by several authors [18], [7], [4], and this finding confirms the low efficiency of this irrigation technology on inputs use. The low efficiency is coherent with results of previous studies [7], [4] in irrigation district “Comunidad de Regantes V” in Bardenas.

In the baseline scenario, all crop acreage is considered under traditional irrigation technology although sprinkler and drip irrigation has been introduced in some areas.

[4] The estimation of yield response for pepper shows problem of convergence during estimation, and the simulation is realized comparing directly yield, percolation and leaching generated by EPIC.

Table 2. Estimated production functions for each crop

Coefficients	Corn	Barley	Wheat	Alfalfa	Sunflower	Rice	Tomato
β_0	-3.838** (0,470)	0,349** (0,147)	0,103 (0,182)	3,086** (0,335)	0,211** ($0,744\cdot10^{-1}$)	0,415** (0,126)	-4,264* (2,017)
β_1	$0,226\cdot10^{-2}$** ($0,145\cdot10^{-3}$)	$0,147\cdot10^{-2}$** ($0,114\cdot10^{-3}$)	$0,149\cdot10^{-2}$** ($0,939\cdot10^{-4}$)	$0,234\cdot10^{-2}$** ($0,755\cdot10^{-4}$)	$0,455\cdot10^{-3}$** ($0,261\cdot10^{-4}$)	$0,558\cdot10^{-3}$** ($0,275\cdot10^{-4}$)	$0,124\cdot10^{-1}$** ($0,440\cdot10^{-3}$)
β_2	$-0,184\cdot10^{-6}$** ($0,121\cdot10^{-7}$)	$-0,314\cdot10^{-6}$** ($0,250\cdot10^{-7}$)	$-0,222\cdot10^{-6}$** ($0,137\cdot10^{-7}$)	$-0,119\cdot10^{-6}$** ($0,460\cdot10^{-8}$)	$-0,498\cdot10^{-7}$** ($0,257\cdot10^{-8}$)	$-0,262\cdot10^{-7}$** ($0,161\cdot10^{-8}$)	$-0,120\cdot10^{-5}$** ($0,388\cdot10^{-7}$)
β_3	$0,312\cdot10^{-1}$** ($0,233\cdot10^{-2}$)	$0,143\cdot10^{-1}$** ($0,280\cdot10^{-2}$)	$0,177\cdot10^{-1}$** ($0,247\cdot10^{-2}$)	$0,700\cdot10^{-2}$ ($0,105\cdot10^{-1}$)	$0,864\cdot10^{-2}$** ($0,121\cdot10^{-2}$)	$0,197\cdot10^{-1}$** ($0,169\cdot10^{-2}$)	0,224** ($0,285\cdot10^{-1}$)
β_4	$-0,540\cdot10^{-4}$** ($0,399\cdot10^{-5}$)	$-0,492\cdot10^{-4}$** ($0,143\cdot10^{-4}$)	$-0,495\cdot10^{-4}$** ($0,879\cdot10^{-5}$)	$0,454\cdot10^{-5}$ ($0,113\cdot10^{-3}$)	$-0,237\cdot10^{-4}$** ($0,589\cdot10^{-5}$)	$-0,105\cdot10^{-3}$** ($0,744\cdot10^{-5}$)	$-0,106\cdot10^{-2}$** ($0,107\cdot10^{-3}$)
β_5	$0,153\cdot10^{-5}$** ($0,194\cdot10^{-6}$)	$0,346\cdot10^{-5}$** ($0,530\cdot10^{-6}$)	$0,184\cdot10^{-5}$** ($0,328\cdot10^{-6}$)	$-0,480\cdot10^{-6}$ ($0,638\cdot10^{-6}$)	$0,635\cdot10^{-6}$** ($0,107\cdot10^{-6}$)	$0,121\cdot10^{-5}$** ($0,957\cdot10^{-6}$)	$0,277\cdot10^{-4}$** ($0,179\cdot10^{-5}$)
R^2 adjusted	0,923	0,929	0,891	0,933	0,878	0,954	0,971

* signification level at 5 percent. ** signification level at 1 percent. Standard error between parentheses.

Table 3. Current management of crops under surface irrigation

Variable	Corn	Barley	Wheat	Alfalfa	Sunflower	Rice	Tomato	Pepper
Yield (Tm/ha)	10,4	4,8	5,4	13,7	2,1	6,3	64,8	14,7
Net revenue (€/ha)	678,7	276,9	410,0	394,7	241,1	972,9	3.984,1	2.363,4
Water (m^3/ha)*	10.000 (49)	3.500 (34)	4.500 (37)	13.700 (48)	8.500 (45)	14.000 (95)	8.200 (49)	8.200 (49)
Nitrogen (kg/ha)**	412 (61)	181 (97)	181 (80)	80 (26)	151 (53)	200 (98)	194 (85)	232 (60)
Percolation (m^3/ha)	5.080	2.380	2.850	7.140	4.700	750 Run-off	4.150	4.160
N Leaching (kg/ha)	159	5	37	59	71	5 Run-off	30	93

* the values within parenthesis show the efficiency (h) of applied water (%): h = e/a, where e is effective water, equal to applied water (a) less percolation. ** the values within parenthesis show the efficiency of applied nitrogen in the plot (%).

The base scenario represents current condition of production, inputs use, crop prices, water and nitrogen prices, and costs and subsidies per hectare for each crop. In the base scenario water price is 0,012 €/m^3 and active nitrogen price is 0,6 €/kg. Under the base scenario, corn, alfalfa, wheat and sunflower occupy 73 percent of surface in the irrigation area "Comarca de Cinca Villas". The net revenue is 38 million of €, water use is 381 hm^3, active nitrogen use is 9.949 metric tons (Tm), labour use is 1.124 UTA (1 UTA = 1.800 hours). The percolation is 126 hm^3 and nitrogen leaching 1.618 Tm.

3.1 *Limit in the irrigation water use*

The table 4 shows the optimal solution results for baseline scenario and alternative scenarios of environmental policies measures, establishment of a standard on inputs use.

Under scenario 1, the irrigation water use per hectare is reduced on 25 and 50 percent. Now days the water resource is overused [7], [4] and is realistic to establish a limit in the irrigation water use per hectare.

In this scenario the annual availability water (W) is reduced, such as it is happened in drought period when storage water in the dam is insufficient.[5] When water use reduction is 25 percent, the cultivated acreage falls slightly and acreage sit-aside increases. Under this scenario the water demand decreases 109 hm^3, and nitrogen demand decreases slightly, only 4 percent (351 Tm), due to the expansion of corn acreage that it uses a large amount of nitrogen.

[5] The water reduction by percentage is a simplified assumption. The reduction is realized on water use in the plot, while that reduction properly of water concession should be realized in the head of irrigation district and the losses in water distribution system or secondary channel should be considered.

Table 4. Results of alternative environmental policy measures in the region

Variable	Base scenario	Scenario 1		Scenario 2
	$P_w = 0{,}012$; $P_n = 0{,}6$	∇ W = 25	∇ W = 50	Limit of nitrogen
Acreage (ha)	60.196	59.599	59.290	60.110
Corn (ha)	10.888	15.072	9.915	11.866
Barley (ha)	5.603	6.110	4.241	5.599
Wheat (ha)	12.229	9.635	7.062	11.263
Alfalfa (ha)	12.987	10.458	7.597	13.095
Sunflower (ha)	7.671	5.668	4.083	5.730
Rice (ha)	4.472	2.120	1.391	4.201
Tomato (ha)	950	510	316	883
Pepper (ha)	625	469	312	605
Set-aside CAP (ha)	4.771	9.557	24.332	6.866
Production value (10^6 €)	62,8	53,6	36,5	55,4
Net revenue (10^6 €)	38,1	34,2	29,3	33,9
Water (hm^3)	381	272	182	346
Nitrogen (Tm)	9.949	9.598	6.462	6.465
Labour (UTA)	1.124	967	665	1.091
Percolation (hm^3)	126	76	49	111
Leaching (Tm)	1.618	935	617	1.018
Revenue per ha (€/ha)	1.043,3	898,5	615,4	922,0
Revenue per m^3 (€/m^3)	0,165	0,197	0,200	0,160
Net revenue per ha (€/ha)	633,6	573,7	494,9	564,0
Net revenue per m^3 (€/m^3)	0,100	0,126	0,161	0,098

The percolation and leaching reduction is substantially, 40 and 42 percent respectively. The cost to farmers of this measure is moderated, since net revenue falls 10 percent.

The water use reduction by 50 percent decreases significantly the cultivated acreage and increases the acreage sit-aside. The water use reduction by 50 percent has a similar effect than increasing water price on 0,09 €/m^3. The fall of nitrogen and labour use is important, close to 40 percent. The contamination reduction is substantially, percolation and leaching decrease 61 percent. The cost to farmer of this measure is high, although the cost is lower than increasing water prices, since net revenue falls by 23 percent (8,8 million of €).

The results of the scenario of limit in irrigation water use shows that water saving possibility with this measure has a low cost compared to increase in water prices. These results are consisted with conclusions of previous study [1].[6] The problem of this measure is the difficulty in monitoring, because the irrigation district associations control only the accomplishment of irrigation turn. However it could reduce the water volume to the irrigation district associations, and let them to administrate the reduction among farmers. In the large irrigation area of public initiative, such is Bardenas, the control is relatively simple. But in the individual abstractions form aquifers the control is much more complicated [11].

3.2 Limit in the nitrogen applied

Under scenario 2, a limit in the active nitrogen applied to the crops is introduced.[7] This instrument is similar to the Code of Good Agricultural Practices, established by the European Nitrate Directive.

[6] Authors [1] indicate that water use reduction by 21, 42 and 57 percent decreases net revenue by 2, 11 and 25 percent, for an irrigation area with corn, wheat, alfalfa, and bean and surface irrigation technology.

[7] The standard for the crop is: corn, 250 kg/ha, barley, wheat, sunflower, rice, and tomato, 100 kg/ha, alfalfa, 50 kg/ha and pepper 125 kg/ha.

The standard in nitrogen applied stimulates the expansion of corn and sit-aside acreage. The water demand falls by 10 percent, and demand nitrogen is reduced at a quarter. The establishment of a limit reduces the leaching in the area on 50 percent (600 Tm). The cost to farmers of this measure is small, since net revenue falls by 11 percent (4,2 million of €). These results coincide with conclusion of previous study [2], [10].

The main problem to implement a limit on nitrogen use is the difficulty in monitoring. This problem could be solved to assign monitoring responsibilities to the irrigation district association through measurement of nitrogen concentration on the return flows. In the irrigation district "Comunidad de Regantes V" monitoring could be achieved, since water quality measurements are already being done on the return flows of the irrigation district [4].

Another feasible option would be the establishment of a control system with higher nitrogen price, the introduction of a subsidy system for farmers who reduce fertilizer application and control emissions verification. The licensing fertilizer application to a specialist, known in literature as "environmental doctor" would be another method of implementing the standard.

Table 5. Cost-efficiency of environmental policy measures

Scenario	Cost (€/kg)*
Limit on water applied (25 %)	5,8
Limit on water applied (50 %)	8,8
Limit on nitrogen applied	7,1

* Cost to reduce the contamination by nitrogen leaching.

The table 5 shows the cost-efficiency of the environmental policy measures. The cost-efficiency is the relationship between loss of net revenue and reduction of nitrogen leaching. The reduction of water use by 25 percent is the best cost-efficiency measure to abate the nitrogen emissions. Other studies in Flumen-Monegros irrigation area [10] and Bardenas [20] indicate that the best measure to abate the contamination by leaching is standard on nitrogen applied, although these works don't consider the limit in the water applied. Previous study [22] indicate that limit in leaching is the first efficient measure, following by a limit in nitrogen and water applied.

4. Conclusion

A bio economic model of agricultural activities in the Bardenas irrigation area of the Ebro basin in Spain is constructed. The model includes production function of crops, estimated with EPIC crop growth package. The model determines the effect of irrigation management measures on acreage and crop yield, water and nitrogen demand, environmental impact, and calculates the cost-efficiency of measures.

In the simulation, the baseline scenario has been compared to alternative scenarios, such as setting a standard on water and nitrogen application. Under the baseline scenario the irrigation system is by surface, and there is an overuse of inputs, water and nitrogen, that generate the large percolation and leaching. Alfalfa, corn, sunflower, tomato and pepper, are the crops with higher water and nitrogen losses.

Under the scenario of establishment a standard on the water application, the cost to farmer is lower than first one, while the effect on the percolation and leaching is similar. This measure is appropriate to avoid the overuse of water resource. The implementing of this measure could require the establishment of concession volume to irrigation district associations, [8] measurement of irrigation districts return flows and control of standard.

The standard on irrigation water applied by 25 percent is more cost-efficiency measure to abate the contamination by nitrogen leaching, and the second best measure is the standard on nitrogen applied following by increasing nitrogen prices. This conclusion is very relevant, since in the majority of works, the study environmental policy measures to

[8] Nowadays don't exist individual concession to irrigation district association in Bardenas, neither in the Mongros irrigation area, although in the drought period is reduced the water assigned. The Ebro Basis Plan establishes maximum water quantity per hectare.

control the contamination is not considered the limit on water applied. The environmental policy measures based in the limit on inputs use, water and nitrogen, are more cost-efficiency instruments to control contamination in irrigation than ones based in increasing inputs prices. An important question in the choice of the best instrument is its implementation cost, and policy maker of contamination control should be including this cost to calculate the efficiency of instrument.

The problem in the choice of appropriate measure depends on the transaction cost, and it should evaluate the welfare loss after application of this instrument. The instrument should establish in function of soil and crops, since that contamination by percolation and leaching depend on both. The discrimination of control environmental policy measure is essential for crops with high pollution potential on vulnerable soils.

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