Working Paper WP02-10 October 2002

WATER POLICY AND THE SUSTAINABILITY OF IRRIGATED SYSTEMS IN ITALY

by
G. Bazzani, S. Di Pasquale, V. Gallerani and D. Viaggi

Prepared for the
8th Joint Conference on Food, Agriculture and the Environment
August 25-28, 2002
Red Cedar Lake, Wisconsin

Sponsored by

Center for International Food and Agricultural Policy
University of Minnesota

Research, Food and Nutrition, Commodity and Trade,
Development Assistance, Natural Resource and Environmental Policy

Working Paper WP02-10 October 2002

WATER POLICY AND THE SUSTAINABILITY OF IRRIGATED SYSTEMS IN ITALY

by
G. Bazzani, S. Di Pasquale, V. Gallerani and D. Viaggi

Information on other titles in this series may be obtained from Waite Library, University of Minnesota, Department of Applied Economics, 1994 Buford Avenue, 232 ClaOff, St. Paul, MN 55108-6040, U.S.A. The Waite Library e-mail address is: lletnes@umn.edu. This paper is available electronically from AgEcon Search at http://agecon.lib.umn.edu.

WATER POLICY AND THE SUSTAINABILITY OF IRRIGATED SYSTEMS IN ITALY[1]

by

G. Bazzani, S. Di Pasquale, V. Gallerani, D. Viaggi

Department of Agricultural Economics and Engineering
University of Bologna
Viale Fanin, 50
40127 Bologna
sabridip@agrsci.unibo.it

prepared for the
8th Joint Conference on Food, Agriculture and the Environment
August 25-28 2002
Red Cedar LakeWisconsin

[1] The paper is a common work of the authors. In particular, G.M. Bazzani has written section 3.1 and 3.2; S. Di Pasquale has written section 2; D.Viaggi has written section 3.3. and 3.4 and V.Gallerani has written section 4. Introduction and conclusions have to be attributed to all the authors.

1. Introduction

Water management requires knowledge of the impact of water use on ecosystems and, as a direct or indirect effect, on human well being, as well as suitable policy tools able to meet social objectives and private behaviour. The legal framework in the EU is today faced with the new water framework directive (WFD) (directive 60/2000) that sets up new criteria for water management, regulation and pricing.

The accompanying economic documents of WFD identify a general structure of the water pricing problem, defining the price as the sum of an element related to fixed cost, a charge per unit of water used and a charge per unit of pollution. Also the principle of full cost recovery (FCR) and the polluter pays principle (PPP) should be taken into account by regulators when setting water pricing.

Agriculture is one of the main water-using sectors, with a share of total water use ranging from 40 to 80% of total water usage for the main EU countries. Italian agriculture relies heavily on water availability and on low water prices. For many areas of Italy, the principles introduced by the directive 60/2000 may be a significant change if compared to present payment criteria, based on traditional rights, political prices and a low degree of cost recovery from farmers.

The objective of this paper is to analyse the water policy for irrigated agriculture, through a simulation model based on the integration of a mathematical decision making model and a principal agent. The methodology allows to quantify water demand and optimal regulation from the point of view of the policy makers. The final aim is to create a support for the economic evaluation of the efficiency of alternative policy instruments for the application of WFD to irrigation.

The paper has the following structure. In section 2 an overview of the situation of irrigated agriculture in Italy is provided. In section 3 the methodology adopted is described, followed, in section 4, by the results. A discussion is provided in the final section

2. The water problem and irrigated agriculture in Italy

In Italy, as in many countries, the issue of water scarcity is rapidly gaining attention. Agriculture plays a major role in such issue, as it is the sector with the higher share in water consumption (around 50% of the total amount of water consumed) due mainly to irrigation.

In Italy a big fraction of the water consumed in agricultural sector is derived from rivers (around 66 percent of the total amount). Only 18 percent comes from wells and springs. About fifty-five percent of the water surface reservois (110 billion m^3 per year) has some economic and physical constraints that make impossible to exploit all of it . Moreover, most of these reservois are located in the North, while the Center and the South with a bigger need in water supply due to recurrent droughts are less endowed. This explains why water supply is still critical despite the reduction in water consumption in the last decade. Water scarcity phenomena are common in several Italian regions. About 12 percent of the total population in Italy is affected by supply discontinuity, with the highest proportion of the phenomenon striking down the South and the Islands.

In 2000 the irrigated land was around 25% of the total agricultural area, with a significant growth in the last decade (in 1993 it was around 18%). The irrigated area has a very different share of total agricultural area in different regions, ranging from 8,2% of Marche, to 66,2% of Lombardia (ISTAT, 2000). For some crops (e.g. orchards, vegetables, flowers) the irrigated area is virtually 100% of the total cultivated area. The 55% of agricultural production is obtained by irrigated systems (Leoni, 1997) and the 60% of Italian agricultural export is made up of irrigated crops (Anbi, 1992; Lamoglie, 2001).

The water distribution system in Italy is mainly managed by "reclamation and irrigation boards" (RIB), that, formally speaking, are associations of farmers that control the management and distribution of water resources over a certain area. Water use regulation is based on a complex system of rights, often developed since ancient times. In Italy, the most common method of water pricing used is an area pricing method, water is charged in a per unit area basis. Volumetric pricing methods are also applied but just in few cases. The Italian market remains highly fragmented. Much of Italy's water utility service is characterized by a large gap between actual tariffs and economic price levels, with investments over the next 15 years estimated at more than euro (Eur) 30 billion.

The introduction of WFD could bring major changes for irrigated farming. Though the application should be strongly differentiated at regional level, according to river basin organisations, some major criteria are common for all countries.

The first is the principle of full cost recovery. According to this principle, the user of water should bear all the costs of water provision. From an agricultural perspective this would mean a net increase of water prices, as today, in Italy, only a part of running costs for water provision are borne by the final users.

A second major principle introduced is the polluter pays principle (PPP). According to the PPP, water users should bear the cost of pollution as well as the costs of the water resources and of water provision. This could make things worse for irrigated farms as long as irrigation is often associated to more intensive farming systems, including a higher use of pollutants.

The water pricing would be a recommended instrument for reducing water use and water pollution. Putting things together, the suggested pricing structure after the WFD is implemented may be made up of at least three components: a fixed amount for unit of irrigated land, a price per unit of water used and a price per unit of pollution. The final price should take into account both the full cost recovery and incentive considerations in order to bring to the best social use of water.

From a farm point of view, the main risk from WFD is the increase in water price[2], which could lead to major impacts on farming income and employment. The evaluation of the impacts of higher water prices and the search for better policies are hence two major issues for agricultural policy making.

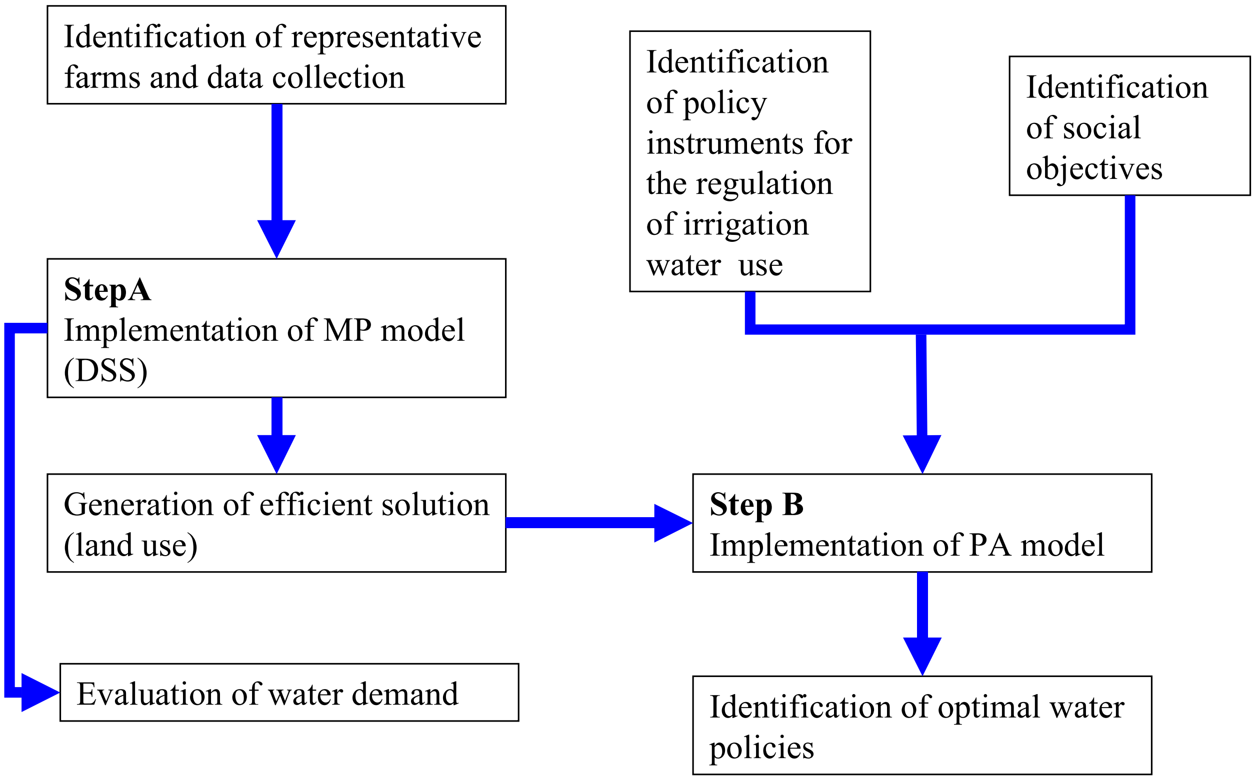
3. Methodology

3.1. The overall methodology

A very wide literature exists about the pricing of water resources related to agriculture, both in terms of policy analysis and in terms of instruments for decision support[3].

The main point of the proposed methodology is the attempt to couple mathematical programming (MP) models and principal agent (PA) models (Figure n.1.).

Figure n.1. Methodology



[2] Actually other instruments, such as usage thresholds during key periods, may be used, but are not considered in this paper.
[3] Only to remind some of the main works related to water, see for example Dinar and Subramanian (1997); Dosi and Easter (2000), Garrido et al. (1999), Gomez et al (2002), Tsur Y.et al (2002).

The first part of the model (step A) is based on the use of mathematical programming. This instrument, frequently used in the literature for irrigation problems, allows the search for optimal crop mix or activity combinations, for representative farms[4]. The problem is cast as a constrained maximization, where constraints include water availability and the objective function is farm profit or net income. The same model also allows the generation of a demand function for water.

This part of the model has been implemented in the form of a Decision Support System (DSS) able to easily allow data entry and provide simulations. The model takes into account the activities required by the production cycle; this allows to analytically quantify the utilisation of water, chemicals, labour and machinery and their costs, considering different irrigation systems at territorial and farm level. The program, which operates as a Windows application, is highly friendly. It can be used at farm level as a decision support tool for technicians and farmers, while at public level it allows to study and define water tariffs and policy, as well as to evaluate the impacts of a territorial transformation due to increase or shortage of water supply.

While the DSS can be used as an independent tool, in the context of the present work its main role is that of generating the set of alternative feasible crop mix that can be adopted by the farm under analysis. The set of feasible crop mix is produced together with income, water consumption and any other useful parameters and can be evaluated through the PA model (step B). The PA model is aimed at identifying the optimal incentive scheme from the point of view of the public regulator, given the opportunity cost of water, the social cost of environmental externalities and the social cost of public transfers (Kreps, 1990; Rasmusen, 1994). It is able to identify the optimal crop mix from a social point of view and the best way to give to the farmer suitable incentives to choose that crop mix. The program used for running the PA model is Gams 2.50.

3.2. The DSS and the identification of feasible crop mix

In the context of this work, the DSS is mainly used in order to estimate valuable combinations of farm activities, useful to be fed into the PA model. Each combination represents a crop mix and other possible activities, such as the choice of a particular irrigation system.

In principle, any possible crop mix could be used as input for the model. Nevertheless, given a linear mathematical problem, the optimisation algorithm of the linear programming would choose the solution among corner points. In order to use the same rationale here, the DSS includes an algorithm able to find the set of possible corner points of the model. The algorithm is based on a parametrization of gross margins of the model. The corner points identified are fed into the PA model.

It is necessary to point out that the corner points identified in such way may or may not be efficient from the private point of view, depending on the actual price combination. Also, each corner point represents a combination of crops and is associated to some economic, social and environmental results. So, from a social point of view, it is possible to express a hierarchy of preferred corner points. The problem is that the hierarchy depends on the social cost of providing incentives to the farmer to produce at that point. Here is where the PA model comes in.

For our purposes the integration between the two models appears particularly useful, as the DSS allows to identify only "relevant" solutions, instead of the infinite possible ones. Also, this avoids problem of infeasibility in the following PA model.

Finally, it allows to verify the results of the PA by feeding them into the MP model.

3.3. The Principal-Agent model with risk neutral farmer

PA models can be used in order to identify optimal regulation parameters given agent's utility function and principal's utility function (Kreps, 1990; Rasmusen, 1994). In our case, we

---

[4] See Bazzani et al. (2001), Berbel (2000), Dono (2001), Howitt (1980), Moore et al (1992, 1994a, 1994b),

assume the existence of a public or semi-public decision maker (a RIB) interested in maximizing the social welfare through the regulation of the irrigation activity of one or more agents (farmers). The problem is to find the optimal regulation taking into account the constraints given by the WFD and the economic relationships between single actors. Let us suppose that there is only one principal and one agent.

We assume that, for our purposes, the behaviour of the farmer may be represented by discrete actions $a_i = \{s_{ij}\}$, each one made up of a vector of values *s* of the decision variables *j* and *i*, whit $i = (1,\ldots, I)$ where *i* represent a plan and *I* a set of possible plans and $j = (1,\ldots, J)$, *j* represents a crop and *J* a set of possible crops, so s_{ij} is an amount of crops *j* in plan *i*. Assuming linear relationships, we can interpret s_{ij} as the degree of activation of each farm activity and a_i as a vector of such degrees of activation in a farm representation that uses a fixed coefficients technology. We assume further that the results (technical, economic and environmental) of each crop depend on some state of nature θ_p, with p = (1,…, P,) each with probability π_p. According to standard technology representation under uncertainty, as a consequence, farm income, water use and environmental results may be represented as a function of the state of nature occurring.

We can assume that the objective function of the public decision maker, concerning the regulation, includes the following components: farm income; value of the water used; value of externalities (positive or negative) produced; costs for water abstraction and delivery, included administrative and transaction costs; distortionary effects due to social transfers (taxes or subsidies); monitoring and control costs.

Assuming that the problem of the principal is to maximize social welfare, it is possible to find out the solution using a two steps procedure (Kreps, 1990; Rasmusen, 1994).

The first consists in finding the least cost solution that guarantees the carrying out of each possible action by the agent. In the second, the aim is to choose the action a_i that maximizes social welfare. While the latter of these steps is quite simple, the first one is rather more complex.

Schaible (1997), Varela-Ortega et al. (1998).

First note that for each farm action, farm income (from market), the value of water used and of externalities produced do not change depending on the devised incentive scheme. So, in order to proceed to cost minimization we have to take into account only the cost of transfer to public authority, the cost of water provision and the cost of control and monitoring. Assuming both the principal and the agent risk neutral, the problem of cost minimization representing our first step may be cast as follows:

$$\min K_i = e\left[\sum_j s_{ij} \cdot \sum_p \pi_p \left(\left|F_j\right| + \sum_h \left|w_h\right| \cdot Q_{jph} + \sum_k \left|b_k\right| \cdot Y_{jpk}\right) + \left|T\right|\right] + Kd \ + Kc \ \cdot f$$

subject to the following constraints:

IC1:

$$\sum_j s_{ij} \cdot \sum_p \pi_p \left[ML_{jp} - \left(F_j + \sum_h \ w_h \cdot Q_{jph} + \sum_k \ b_k \cdot Y_{jpk}\right)\right] \geq$$
$$\sum_j s_{i'j} \cdot \sum_p \pi_p \left[ML_{jp} - \left(F_j + \sum_h \ w_h Q_{jph} + \sum_k \ b_k \cdot Y_{jpk}\right)\right]$$

for any i’ different from i.

IC2:

$$\sum_j s_{ij} \cdot \sum_p \pi_p \left[ML_{jp} - \left(F_j + \sum_h \ w_h Q_{jph} + \sum_k \ b_k \cdot Y_{jpk}\right)\right] \geq \sum_j s_{ij} \cdot \sum_p \pi_p (ML_{jp} - f \ \cdot S)$$

BC:

$$\sum_j s_{ij} \cdot \sum_p \pi_p \left(F_j + \sum_h \ w_h Q_{jph} + \sum_k \ b_k \cdot Y_{jpk}\right) + T \geq Kd \ + Kc \ \cdot f$$

Where:

K_i = social cost of action i;

ML_{jp} = gross margin of the activity j;
e = distortionary effect caused by taxation
Q_{jph} = quantity of water consumed by each activity j;
Y_{jpk} = quantity of pollutant produced by each activity j;
v_h = unit social value of water (opportunity cost) by period h;
z_k = unit social value (positive or negative) of each environmental parameter k;
Kd = abstraction and distribution costs of the RIB;
Kc = monitoring costs able to guarantee 100% compliance and sure information transfer (f=1);
T = public (state) transfers obtained by the RIB;
S = sanction in case of non-compliance.

In this problem, the decision variables are the following:

F_j = fixed charge per unit of activation (land) of each activity (crop); it may be positive or negative (subsidy);
w_h = charge per unit of water used in each period h;
b_k = charge per unit of environmental parameter k;
f = level of monitoring accuracy (0-1);

The result of this constrained optimization is a bundle of regulation parameters. This bundle represents the least cost solution able to persuade the farmer to accept each of the different action considered in the evaluation. The model is based on the minimization of social cost subject to three constraints.

The social cost is the sum of the social cost of public transfers, the cost of water provision and monitoring cost. Monitoring costs are the result of the cost of total control times the level of monitoring accuracy, following a modified version of the linear monitoring cost used by Choe and Fraser (1999). While costs for monitoring and water provision are fully considered in the public decision maker objective function, transfers account are considered only for a fraction, determined by the distortionary effect of taxation (e), i.e. the inefficiency due to the subtraction of money from the private sector (White and Ozanne, 1997).

A participation constraint is not needed as long as any farmer included in the area of the RIB has to submit to charges for irrigation (farmers are not free to chose to participate or not).

Equation IC1 is a standard incentive constraint of a PA model. It guarantees that the regulation framework is such that each action considered is better than any of the others, for the same farm. In the presence of the bundle of incentives produced by the model, the farmer will choose that action and not another.

Equation IC2 guarantees that it is more profitable to comply and tell the truth to the regulation body instead of doing the opposite. It contains a sanction that, in this context, is assumed as an exogenous variable. The structure of the model implies that the regulator is interested in obtaining full compliance.

Equation BC is the balance constraint for the regulatory body. It guarantees that, according to the WFD, the regulating body achieves a FCV.

IC2 and BC contribute mainly to determine the total amount of payment requested to the farmer, while IC1 directly affects the level of charges/subsidies for each activity.

The model can of course be simplified or made more complete in many ways. One way is to consider more than one farm, with possibly different characteristics. In this case, a constraint could be added, managing the differentiation of incentives in order to overcome adverse selection.

Also, decision variables may be structured in a different way, allowing for different variability of incentive schemes. For example charges per hectare can be the same for all crops and not differentiated between crops as in the model. Of course these options have to be matched with the actual policy relevance and feasibility of each area in which the model is applied.

The second step is simply carried out by choosing the action that maximizes social benefit B:

$$B_i = \sum_p \pi_p \sum_j s_{ij} \cdot \left[ML_{jp} - \left(\sum_h v_h \cdot Q_{jhp} + \sum_k z_k \cdot Y_{jkp} \right) \right] - K_i$$

In this case the social benefit is composed by the farmer's gross margin, minus the value of the externalities produced, minus the social cost of the regulation determined in the previous step. In case of positive externalities the formulation still holds and the value of the externalities sum to the gross margin. Other structures of the benefit function may be associated to different social objectives or to different actors.

3.4. The Principal-Agent model with risk averse farmer

Risk aversion by the agent has been considered in order to provide a first evaluation of its relevance and direction in affecting the results.

When we introduce risk aversion by the agent, we have to revise the constraints IC1 and IC2. According to the literature, we assume the "textbook" representation in which the expected utility is given by the sum over the possible states of nature of the square root of the income in each state of nature. In order to take into account that incentives may be both positive and negative, so may add or subtract to income, we use a slightly modified representation in which the square root is taken separately for the positive part and for the negative part of the incentive scheme (see also Choe and Fraser, 1999 about this issue).

In effects, the regulation parameters may be both positive or negative, i.e. may be charges (when positive) or subsidies (when negative). We denote F_j^+ as the positive charge per hectare of each activity (crop); w_h^+ as the positive charge per unit of water used in each period *h* and b_k^+ the positive charge per unit of environmental parameter *k*. Instead we denote the decision variables as F_j^-, w_h^-, b_k^- when they are negative charges (i.e. subsidies).

Also, we denote with E_{jp}^+, the sum of positive charges per unit of activity and state of nature, as:

$$E_{jp}^+ = \left(F_j^+ + \sum_h w_h^+ \cdot Q_{jhp} + \sum_k b_k^+ \cdot Y_{jkp} \right)$$

and respectively E_{jp}^- as the sum of negative charges.

So we can rewrite our constraints as:

IC1:

$$\sum_p \pi_p \left\{ \left[\sum_j s_{ij} \cdot \left(ML_{jp} - E_{jp}^- \right) \right]^{1/2} - \left(\sum_j s_{ij} \cdot E_{jp}^+ \right)^{1/2} \right\} \geq$$

$$\sum_p \pi_p \left\{ \left[\sum_j s_{i'j} \cdot \left(ML_{jp} - E_{jp}^- \right) \right]^{1/2} - \left(\sum_j s_{i'j} \cdot E_{jp}^+ \right)^{1/2} \right\}$$ for any i' different from i.

IC2:

$$\sum_p \pi_p \left\{ \left[\sum_j s_{ij} \cdot \left(ML_{jp} - E_{jp}^- \right) \right]^{1/2} - \left(\sum_j s_{ij} \cdot E_{jp}^+ \right)^{1/2} \right\} \geq$$

$$\sum_p \pi_p \left\{ \sum_j s_{ij} \cdot (ML_{jp} - f \cdot S) \right\}^{1/2}$$

This representation also avoids problems with non-positive income that may occur for some actions.

We must note that this solution is not completely satisfying from at least two points of view. First, it is not sure that the square root represents the actual degree of preference of the farmer. Also, by dividing the function into two parts, though the main mathematical requirements are satisfied, we further affect the relative magnitude of utility differentials between different solutions. It is not the aim of this paper to further discuss this issue, adding to the growing literature about risk representation for farming decision making (see, for example, Saxowsky and Wachenheim, 2001; Pennings and Garcia, 2001). At this stage of the research, this solution is considered sufficient to get some first insights into the problem of the connection to risk aversion.

4. Results

The model has been tested on a hypothetical farm that may be considered representative of a very common agricultural system of the province of Bologna (Emilia-Romagna, in the south of the

Po Valley), based on cereal cultivation, coupled with industrial cultivation of vegetables such as potato and onion. Potato, in particular, finds here a very good production environment, and is protected through a local trademark. It relies very much on water availability in order to improve production and to reduce yield variability[5].

The farm has 15 hectares of arable crops and is specialised in a potato-cereal rotation. It is analysed using only one environmental indicator and a constant social cost for water across irrigation periods during the year.

Through parametrisation of the DSS, 81 alternative crop mix have been identified as corner points, i.e. locally efficient solutions, of the MP tool. Such alternative crop mix have been introduced in the PA model for different levels of social cost of water consumption and of nitrogen emission. In this way, the optimal (maximizing social benefit) crop mix for each combination of value of resources/externalities have been obtained.

Figures n.2.a and n.2.b represent the mapping of the optimal crop mix given different combinations of the value of water and the value of environmental externalities. Table n.2 represents the composition of the selected crop mix and their results at farm and social level (for both risk neutral and risk averse farmers).

[5] We also assume e=0,2 (drawn from the literature, see White and Ozanne, 1997), Kd=1600 euro/year and Kc=2500 euro/year (both estimated on the basis of local data).

Figure n.2.a. Dominant solutions for different levels of social cost of water (euro/m^3) and environmental damage by nitrogen (euro/kg) - risk neutral farmer

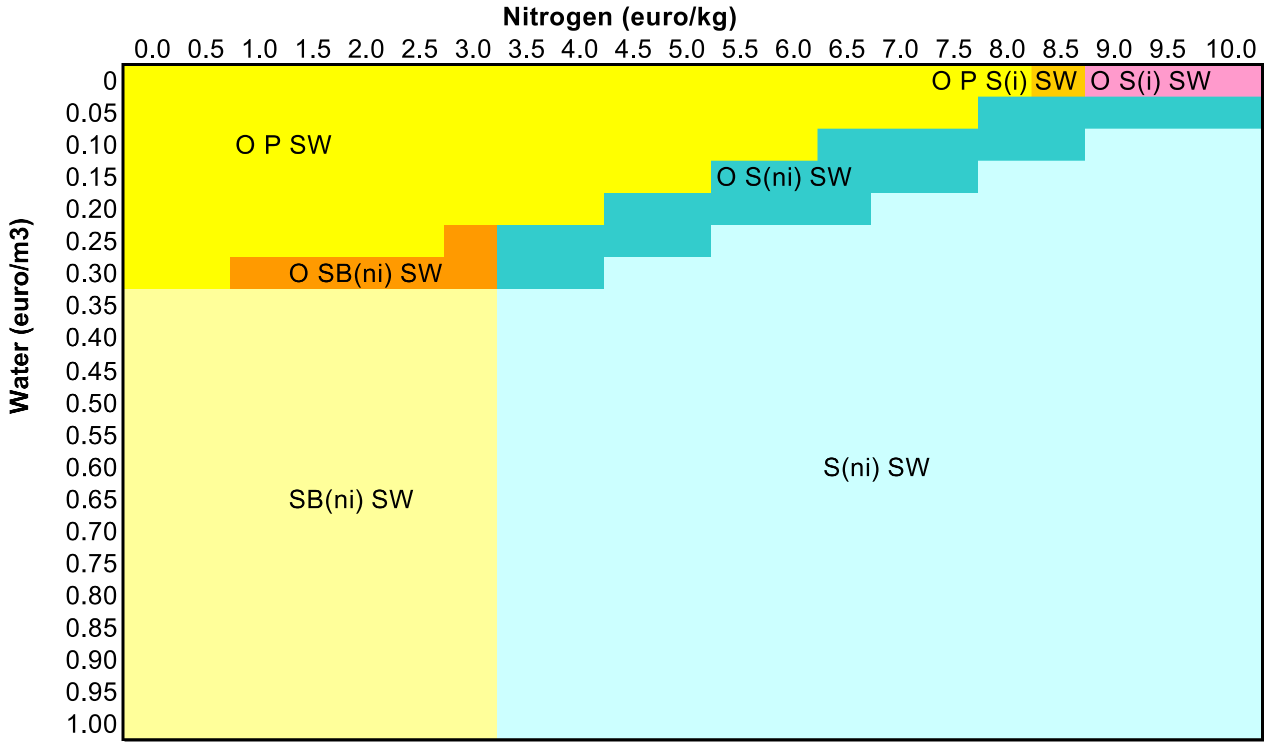


Figure n.2.b. The dominant solutions for different levels of social cost of water (euro/m^3) and environmental damage by nitrogen (euro/kg) - risk averse farmer

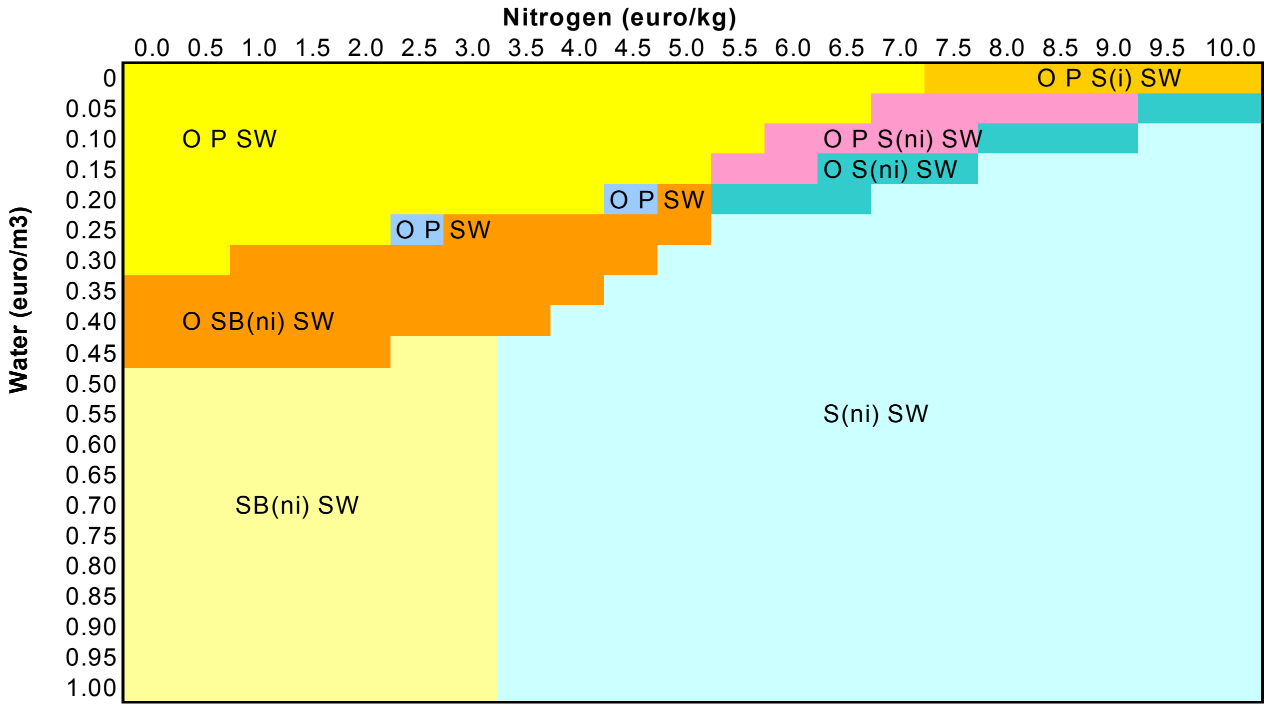


Table n.2. - Dominant crop mix (ha)

	O P SW	O P S(i) SW	O P SW	O P S(ni) SW	O SB(ni) SW	O S(i) SW	O S(ni) SW	SB(ni) SW	S(ni) SW
Onion (i)	3	3	3	3	3	3	3		
Potato (i)	6	5	4.5	5					
Sugar Beet (ni)					4.5			7.5	
Sugar Beet (i)									
Maize (ni)									
Maize (i)									
Soya (ni)				2			4.5		7.5
Soya (i)		2				4.5			
Durum Wheat (ni)									
Soft Wheat (ni)	6	5	7.5	5	7.5	7.5	7.5	7.5	7.5
Barley (ni)									
Irrigation plant	4.5	5	3.75	4	1.5	3.75	1.5	0	0

Gross margin (without incentives) (euro)	**18466**	**18366**	**18398**	**18385**	**14581**	**13854**	**13789**	**13050**	**11730**
Transfer costs (RN)	443	615	626	624	443	443	443	443	443
Monitoring costs (RN)	615	615	615	615	615	615	615	615	615
Water provision cost (RN)	1600	1600	1600	1600	1600	1600	1600	1600	1600
Total policy cost (RN)	**2658**	**2830**	**2841**	**2840**	**2658**	**2658**	**2658**	**2658**	**2658**
Gross margin (after incentives) (RN)	**16250**	**15292**	**15267**	**15263**	**12365**	**11639**	**11573**	**10835**	**9515**
Transfer costs (RA)	432	440	428	436	429	442	442	441	441
Monitoring costs (RA)	559	602	539	578	547	608	607	607	605
Water provision cost (RA)	1600	1600	1600	1600	1600	1600	1600	1600	1600
Total policy cost (RA)	**2591**	**2642**	**2567**	**2613**	**2576**	**2649**	**2649**	**2649**	**2646**
Gross margin after incentives) (RA)	**16306**	**15306**	**15344**	**15301**	**12434**	**11647**	**11581**	**10843**	**9525**

Note: i=irrigated; ni=non irrigated; RN=risk neutral farmer; RA=risk averse farmer.

As it may be expected, increasing the social cost of water, the optimal solution shifts towards non-irrigated crop mix[6]. Two things are worth to be pointed out. First, the move from irrigated to non irrigated crop mix happens for values of water above 0,3 euro, about 6-10 ten times higher than the actual price. This is due to the high value of agricultural production obtained through irrigation. Secondly, above this level the crop mix change dramatically, without relevant substitution between irrigated crops. This is due partly to the actual economic relationship between different crops. Potato and Onion are the two main crops using water. When the social value of water is so high that it is not worth to use it for such crops, it tends to be unlikely that it is worth to use it for any other combination. This effect is made more important, in actual decision making, by rigidities and technical constraints, that make the adaptation a discontinuous matter instead of a smooth process towards less water consuming crops.

[6] It is necessary to point out that the figures do not represent water demand, but socially optimal crop rates depending on the value of water, the value of externalities and the best regulation mechanism identified.

On the other side it is necessary to note that, in this case, the shift towards non irrigated crops is helped by CAP subsidies of which wheat and soya benefit, while potato, onion and sugar beet do not. In their absence, the shift would be surely slower. Another consequence is that the shift towards dry farming would mean, in this case, an increase in CAP payment[7].

When assuming a risk averse farmer, the move is slower. This is due to the fact that non-irrigated sugar beet, maize or soya are needed in the dry solutions (for rotation reasons) but are also the crops with the higher variability of yields. This means that higher incentives are needed in order to persuade the farmer to shift towards such crop mix. Basically, risk aversion appears to slow down the hypothetical change towards less water consuming farming, as they are, at least partially, associated with higher variability.

The payments account for about 14-16% of the gross margin. Their total amount is mainly determined by the costs for water provision and monitoring. The shift towards non-irrigated crop mix causes a reduction in farm income (-37% in the extreme case). It is also associated to a dramatic change in labour organisation, due to the move towards much less intensive crops.

The total social cost of intervention is almost the same in every case. Small variations, within a range of less then 10%, may be found both for different crop mix and between risk and non risk farmer. According to the result obtained up to now, hence, risk aversion does not appear to change very much the total cost of the incentive scheme.

The results are obtained supposing the use of the optimal regulation system for each crop mix, that is illustrated, for a risk neutral farmer, in table n.3.a.

[7] They have not been considered in the utility function of the RIB for two reasons. The first is that they come from the EU and it is likely that the local decision maker is less interested in the social cost of their use. Secondly, they may be considered as a "due" support to farm income and not as a part of an incentive payment for controlling agriculture production and its environmental consequences.

Table n.3.a. - Optimal regulation scheme for each crop mix – risk neutral farmer

	O P SW	O P S(i) SW	O SB(ni) SW	O S(i) SW	O S(ni) SW	SB(ni) SW	S(ni) SW
Monitoring accuracy	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Tax per crop (euro £/ha)							
Durum **W**heat (ni)						117.0	117.0
Sugar **B**eet (ni)				161.4	176.0	39.4	215.4
Sugar **B**eet (i)		89.1		126.4	113.9	11.9	58.3
Soft **W**heat (ni)	139.0	139.0	139.0	139.0		256.0	256.0
Barley (ni)						7.4	
Maize (ni)				129.4	144.0	106.5	183.4
Maize (i)		165.1	91.6	221.9	201.6		127.5
Soya (ni)							39.4
Soya (i)							
Potato (i)	79.3	389.9	553.9	600.0	600.0	600.0	600.0
Onion (i)	301.9		241.0	204.0	190.8	370.5	466.8
Tax per irrigation plant (euro/unit)							
Tax on water (euro/m^3)							
period 1			0.15	0.18	0.20	0.18	0.26
period 2							
period 3					0.03		0.12
Environmental Tax (euro/kg N) n							

The model allows for a mix of instruments that are only partially used in the selected crop mix, but are widely used throughout other crop mix that are not represented here.

Basically, the optimal solutions are a mix of taxation per crop and charges per unit of water use. In strictly economic terms, taxes per crops are the less expensive instrument for the public administration. In addition, they can be used when water consumption is not measurable (which is very frequent in Italy). On the other side, charges per unit of water consumption are more effective in inducing a change in technology towards water saving technologies.

When taxes are applied, they show to be very high compared to the present tariffs (even 20 times higher). Taxes on nitrogen are basically non necessary due to substantial correlation between water and nitrogen use. The level of accuracy of monitoring tends to be equal between different crop mix and to stick to the upper bound.

The regulation scheme appears rather different when the farmer is assumed to be risk averse (table n.3.b).

Table n.3.b. - Optimal regulation scheme for each crop mix – risk averse farmer

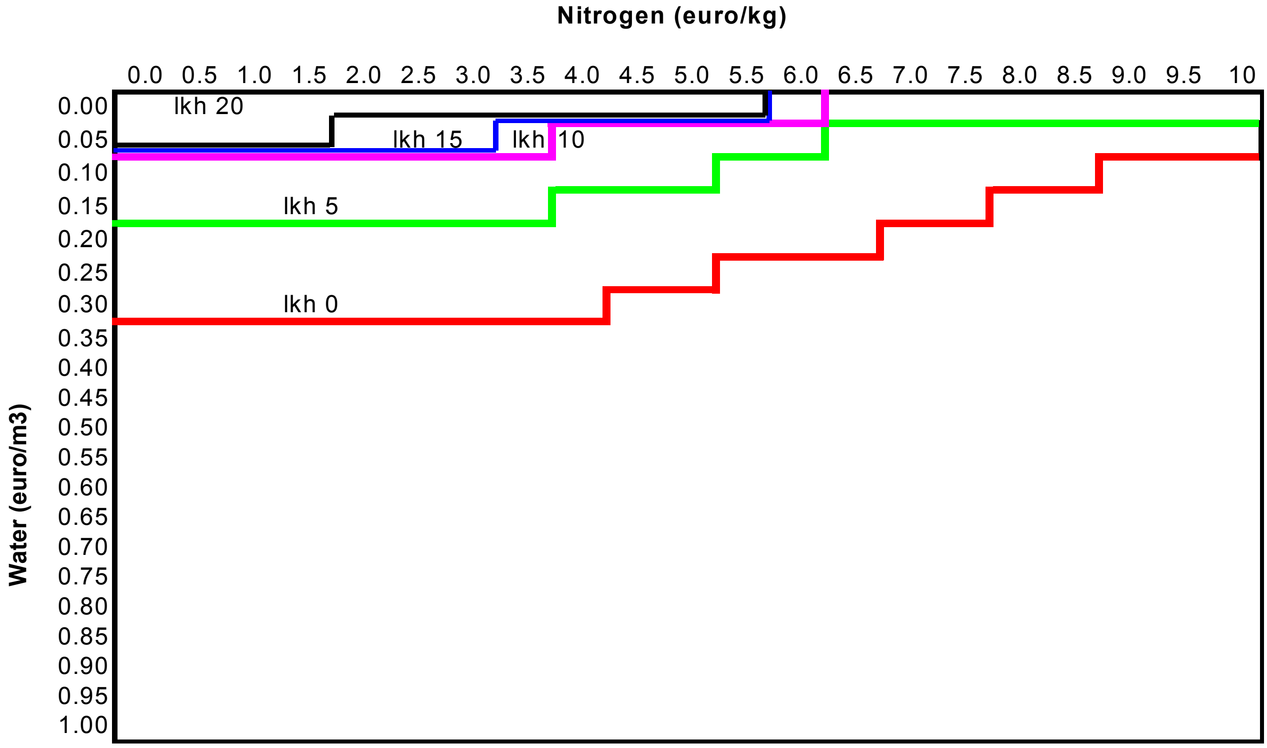
	O P SW	O P S(i) SW	O P SW	O P S(ni) SW	O SB(ni) SW	O S(ni) SW	SB(ni) SW	S(ni) SW
Monitoring accuracy	0.22	0.24	0.22	0.23	0.22	0.24	0.24	0.24
Tax per crop (euro £/ha)								
Durum **W**heat (ni)	5.4	44.35		49.8				
Sugar **B**eet (ni)	60.7	52.95	131.2	59.7	188.9			
Sugar **B**eet (i)								
Soft **W**heat (ni)	35.4	91.58		94.4				
Barley (ni)		25.85		26.07				
Maize (ni)	53.2	41.66	123.09	47.9	178.4			
Maize (i)		11.89						
Soya (ni)	26.9		88.4		133.5	7.3	95.9	
Soya (i)			8.4			16.6	94.0	11.5
Potato (i)		84.65		23.0			76.4	
Onion (i)							155.4	
Tax per irrigation plant (euro/unit)								
Tax on water (euro/m^3)								
period 1		0.15					0.04	
period 2	0.27		0.38	0.26	0.94		0.03	
period 3								
Environmental Tax (euro/kg N)								
n						4.53	3.16	7.35

Some crops are not charged anymore while others are charged more than before. Generally speaking, charges per hectare appear lower than before and less distributed across different crops. Payments per unit of water used and payment per unit of nitrogen are generally higher. In particular, the most extreme (less privately profitable) crop mix are obtained by very strong payments on nitrogen consumption. Altogether, with a risk averse farmer, the optimal policy sees a shift of uncertainty from the farmer (risk averse) to the RIB (risk neutral), leading to a completely different outcome in terms of regulation scheme.

The results showed up to now are heavily affected by the assumptions made about labour cost being equal to zero. Though this is usually regarded as a reasonable assumption, the actual behaviour of farmers shows often that some value is attributed to their own labour. Nevertheless, as the farm is family run, it is not straightforward to attribute a value to the labour employed.

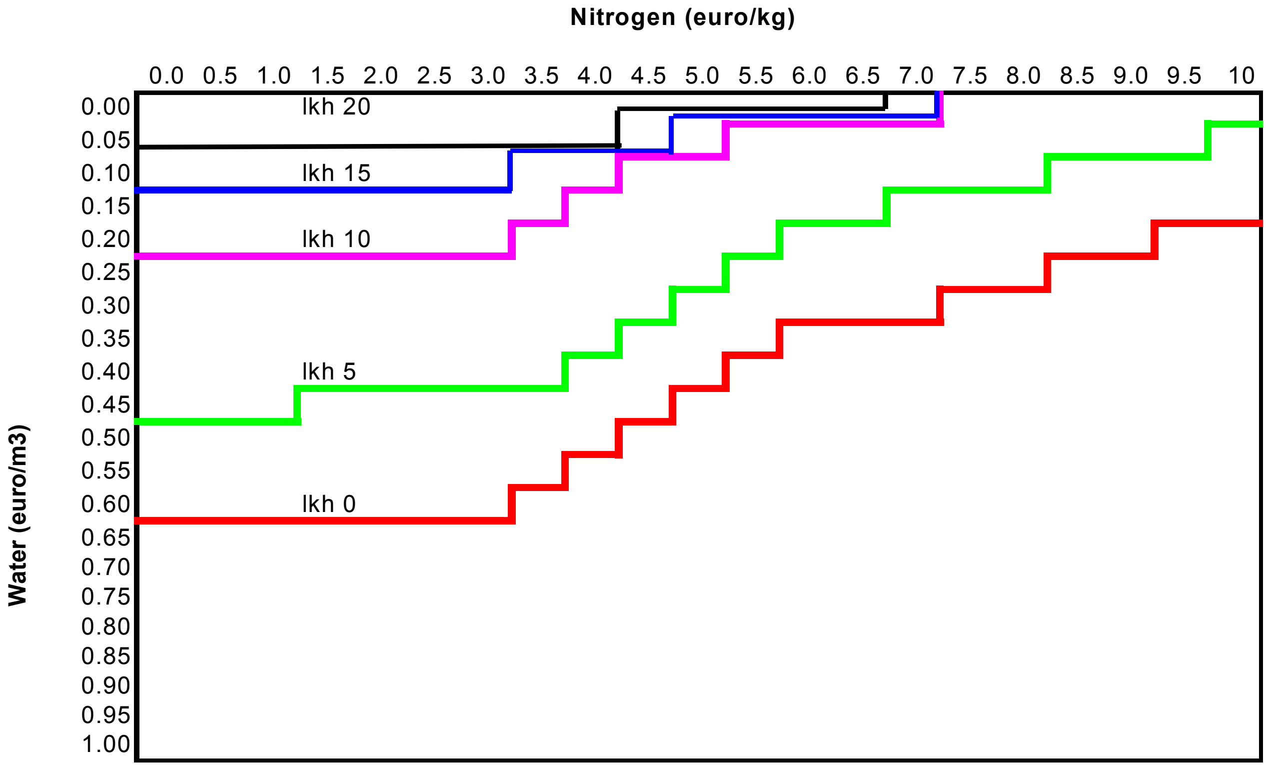
Table n.4. shows the effects of labour cost on the crop mix for different levels of social cost of water and environmental damage by nitrogen (case of neutral farmer). In table n. 4.a. the borderlines depict the border between plans composed by irrigated crops (above of every border) and plans composed of non irrigated crops (below of every border). This table shows that increasing the labour cost, the irrigated solutions are less profitable and the crop mix shifts suddenly to rain fed even for relatively low levels of social cost of water and environmental damage by nitrogen. We can observe the same kind of result in the risk averse farmer behaviour (table n 4.b.). If the cost of labour is equal to zero, the optimal crop mix switch to non irrigated plans for values of water equal to 0.6 euro while in the opposite case (labour cost equal to 20 euro/hour) it falls down to 0.05 euro/m^3.

Table n.4.a. - Borderlines between irrigated and non-irrigated plans for different levels of labour cost (euro/hour) – risk neutral.



Note: lkh =labour cost (euro/hour)

Table n.4.b. - Borderlines between irrigated and non irrigated plans for different levels of labour cost (euro/hour) – risk averse



Note: lkh =labour cost (euro/hour)

While the cost of labour equal to 20 euro/hour may be consider a very high opportunity cost in non farm activities, 10 euro/hour is a reasonable cost to the farm of employing hired work. The effect of labour cost is associated to the most intensive crops, potato and onion, that use high quantities of labour and water as well. An increase in labour cost or, simply, a shift towards more young and more educated farmers, that actually perceive the opportunity cost of non farming activities, can hence have a major role in inducing a reduction of water consumption.

5. Discussion

The model described in this paper allows the simulation of water management as the interaction between a regulating body and a farmer, allowing to quantify the optimal regulation from the point of view of the policy maker.

The results of the case study show that major changes are needed in crop choice in order to meet increasing social value given to water resources and pollution. On the other side, if such values translate into actual policies, they are likely to have major impacts on farm income and organisation. This confirms the relevance of the issue for farming management and policy, and the need of a suitable decision making system based on effective instruments as those presented in this paper.

The adoption of a mix of pricing instruments can significantly improve water policy efficiency, though the degree of such improvement depends on the technical relation between water consumption and each other parameter considered (e.g. environmental indicators).

Risk aversion by farmers tends to produce a slower adaptation to water prices, no much changes in the total amount of incentives needed, but relevant implications in term of optimal instrument combination.

The results of the model, as it is showed by the sensitivity to labour cost, have to be cast in the overall scenarios concerning agriculture in Italy. Through the depopulation of rural areas and the increasing share of educated and young people, the income expectations from agriculture increase and the availability to work with an under remuneration of own labour decrease in turn. Given the trend in farming population in Italy, it is likely that the problem of exceeding water use for irrigation, at least in this area, will be more impacted by demographic and social trends instead that by policy instruments.

Nevertheless, the WFD appears as an occasion for a major revision of water regulation throughout Europe. Some of such revisions, as in the present papers, appear in contrast with the social ad economic objectives of farmers as well as with economic, social and environmental objectives of CAP. Nevertheless the reform of water regulation should be better interpreted in a proactive way as the occasion to anticipate potentially growing conflicts and to make water use altogether more sustainable.

From a methodological point of view, the approach used in this paper show to be able to provide a broad as well as analytical view of the problem. A number of improvements can be carried out on the model, with particular attention to a more reliable way of getting to a better estimation of the actual impact of risk. Further, the analysis should be widened in order to take into account a larger number of crops and a higher number of technologies, included different irrigation systems. One issue that call for a major attention is the role of positive externalities produced by the us of water in agriculture, that is likely to add more rationale to a lower pricing of water.

References

ANBI (1992): *L'uso irriguo delle acque*, Associazione Nazionale Bonifiche Irrigazioni Miglioramenti Fondiari.

Baroncini E. (1998): La gestione delle acque in Italia e le prospettive di sviluppo del sistema infrastrutturale, *Genio Rurale*, n. 10.

Bazzani G.M., Caggiati P., Rosselli Del Turco C. (2001): Dsirr: A Decision Support System For An Economic-Environmental Assessment Of Agricultural Irrigation And Water Policy Design, paper presented at *"Transnational workshop on managing water demand in agriculture through pricing"*, 24-26 May 2001 - Telese terme, Italy.

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

Brooke A., Kendrick D., Meeraus A. (1992): *GAMS A user's guide*, The Scientific Press.

Choe C. e Fraser I. (1999): Compliance monitoring and agri-environmental policy, *Journal of agricultural economics*, 50, 3, pp. 468-487.

Dinar, A. and Subramanian A. (1997): *Water Pricing Experiences. An International Perspective.* World Bank Technical Paper No. 386. Washington, DC.

Dono G. and Severini S. (2001): The impact of the Agenda 2000 CAP Reform on irrigation water use: a regional programming model for a Central Italy horticultural area, paper presented at *"Transnational workshop on managing water demand in agriculture through pricing"*, 24-26 May 2001 - Telese terme, Italy

Dosi C, Easter K.W. (2000): *Water Scarsity: Economic Approaches to Improving Management*, Working Paper WP00-2, University of Minnesota, Dept. Applied Economics.

Easter K. W., Smith R., (2002); Do institutional limitations block the Enlargement of Water Markets, *Agadir Conference, Irrigation Water policies: micro and macro considerations*, Morocco , June 15- 17.

Garrido A., Iglesias E., Kujal P. (1999): Testing Some Provisions of the Recently Created Water Markets on Spain, Awarded proposal by IFREE/ESL Madrid Post-Conference Prize, Tinker Foundation, New York.

Gomez Limon J.A., Riesgo L. (2002): Irrigation water pricing: differential impacts on irrigated farms, *Agadir Conference, Irrigation Water policies: micro and macro considerations*, Morocco , June 15- 17.

Howitt, R.E., Watson W.D. and Adams R.M. (1980): A Reevaluation of Price Elasticities for Irrigation Water. *Water Resources Research* 16, 623-28.

Istat (1991): Statistiche delle acque, Roma

ISTAT (2000): *Statistiche ambientali*, Roma.

Kreps D.M. (1990), *A course in microeconomic theory*, Harvester Wheatsheaf, New York.

Lamoglie C. (2001). L'acqua, un bene prezioso, *L'informatore agrario*, n. 15.

Leone G.(1997): *Stato delle Irrigazione in Italia*, Comunicazione diretta

Massarutto A. (2002): Irrigation water demand in Europe; the impact of Agenda 2000 and the Water framework Directive, *Agadir Conference, Irrigation Water policies: micro and macro considerations*, Morocco, June 15- 17.

Medici G.(1980): *L'irrigazione in Italia dati e commenti*, Edagricole

Moore M.R. and Negri D.H. (1992): A Multicrop Model of Irrigated Agriculture, Applied to Water Allocation Policy of the Bureau of Reclamation, *Journal of Agricultural and Resource Economics* 17: 29-43.

Moore, M.R., Gollehon N.R. and Carey M.B. (1994a): Multicrop Production Decissions in Western Irrigated Agriculture: The Role of Water Price. *American Journal of Agricultural Economics* 76: 859-874.

Moore, M.R., Gollehon N.R. and Carey M.B. (1994b): Alternative models of input allocation in multicrop systems: Irrigation water in the Central Plains, United States. Agricultural Economics 11: 143- 158, 1994b.

Pennings J.M.E. and Garcia P. (2001): Measuring producers' risk preferences: a global risk-attitude construct, *American Journal of Agricultural Economics*, 83(4) pp.993-1009.

Rasmusen (1994): *Games and information*, Second edition, Blackwell, Cambridge MA.

Rosegrant M.W., Ximing Cai (2002): Water Prices, Environment and Food Security, *Agadir Conference, Irrigation Water policies: micro and macro considerations*, Morocco, June 15-17.

Saxowsky D.M. and Wachenheim C.J. (2001): Profits and risk: fitting an old framework to a new agriculture, *Western Agricultural Economics Association Annual Meeting*, Logan, Utah, July 2001.

Schaible G.D. (1997): Water Conservation Policy Analysis: An Interregional, Multi-Output, Primal-Dual Optimization Approach. *American Journal of Agricultural Economics* 79: 163-177, 1997.

Tsur Y., Dinar A., Doukkali R.M., Roe T.L. (2002): Efficiency and Equity Implications of Irrigation Water Pricing, *Agadir Conference, Irrigation Water policies: micro and macro considerations*, Morocco, June 15- 17.

Varela-Ortega C., Sumpsi J.M., Garrido A., Blanco M. e Iglesias E. (1998): Water Pricing Policies, Public Decision Making and Farmers response: Implications for Water Policy., *Agricultural Economics*.

White B. and Ozanne A. (1997): Asymmetric information and agri-environmental policy: a principal-agent approach, *AES Annual Conference*, Edimburgh.