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« Information revelation through  
irrigation water pricing using volume  
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# Information revelation through irrigation water pricing using volume reservations

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## Abstract

We study the properties of a pricing rule for irrigation water with two variables: the volume consumed by the farmer and the volume he/she reserves before the plantation. With a simple deterministic model, we show how this pricing rule allows the Water User Association manager to anticipate any possible usage conflict thanks to farmer information revelation, to guarantee his/her association budget equilibrium. We show too how farmers are incited to restrain their use of water. Moreover this pricing method is fair (all farmers are equally treated), flexible through the possible change of the value of the parameters, and moreover simple and easily understandable (when for example translated in a double entry table). Therefore, it compares favorably to other classical water pricing methods.

**JEL-Classification:** C61, C72, Q25

**Keywords:** water, irrigation, economics, price.

# 1 Introduction

It is now well recognized that an efficient management of scarce water resources is crucial for guaranteeing the sustainability of agriculture in many countries with structural or periodic water deficit. Moreover, as competition with other sectors (urban, industrial and environmental) increases, irrigation is often criticized as a waste of a precious resource (see for example Elnabousi, 2008). In France for example, an increase of irrigated areas in the last decades has led, in case of drought, to severe degradation of the environment and to inefficient administrative banning on water uses. As in many other countries (see for example Almahdi et al., 2007, for Australia), despite its modest role in the national product, agriculture is by far the first sector of water consumption in France, when the resource is rare. Meanwhile this practice will probably not diminish at a time of increased agricultural product demand. Thus new policies and approaches need to be designed to improve water management strategies.

In France, after having built many individual or collective dams in order to increase water-storage capacity (“supply management”), efforts are currently focused on “demand management,” i.e. the use of less irrigation water for the same production and the search for more efficient alternatives for sharing water among the different uses, while trying to find more efficient water-pricing schemes (Garcia and Reynaud, 2004).

But in this country, the fact that by law the water does not belong to anybody (contrary to what happens for example in the USA, see Petrie et Taylor, 2007) does not allow an efficient use of market based instruments. In practice, if we put aside independent farmers with their own dam or well, generally the agents pay a price to their water user associations (WUA) which does not reflect the scarcity of the resource but aims at balancing the WUA budget. Moreover, France tries to impose a tax on water use, but the money collected in this way does not return to the agricultural sector. The farmers’ opposition to such taxation is therefore quite understandable, even when its low level does not reduce water consumption for irrigation in the slightest. Partial or total bans are therefore a current tool, decreasing de facto the water use, but with some adverse effects, as inefficient economic results: farmers cannot irrigate thirsty plants in which they invested time and money, while they could have chosen other less water demanding cultures. Besides these bans lead to an over-equipment in irrigation material, in order to get around such compulsory rules, typically by irrigating more intensely when access to water is not forbidden.

Our objective is then to study if, at the expense of a slight complication of the pricing rule, it would not be possible at least to reveal some information on the water demand by the farmers, far before the summer, in order to anticipate crises, and to give the farmers the possibility to change their culture choices in order to adapt them more precisely to the available water.

The aims of water management are multiple and may sometimes be understood as contradictory (Johansson et al., 2002): The first one is to allocate water to users who valorize it at the best (efficiency). The second is to guarantee an access to this essential good to everybody and to be acceptable in order to be applied (equity). Moreover, as mentioned by Perry (2001), it may be a tool to redistribute public investment benefits. The third is to recover costs induced by water extraction/distribution/use. We may emphasize on this subject that the European Union Water Framework Directive (European Union, 2000), has an entire article dedicated to cost recovery for water services. The fourth is to be transparent and simple enough to be understandable, and it is clear that a two variable tariff as the one presented here is quite acceptable as shown by the spread of the use of futures and other sophisticated financial tools by farmers, and more specifically by the generalization of reservations in everyday life (transportation...).

Generally speaking, water pricing practices can be classified in two families: volumetric and non-volumetric methods. Volumetric methods rely on the volume and require metered water facility. Non-volumetric methods are based on output/input other than water, e.g. in the agricultural sector a per area pricing (Johansson, 2000). The last method are widespread because of their simplicity but they do not encourage to save water.

The volumetric rate pricing depends only on the quantity of consumed water (see Burt, 2007). This type of pricing does not guarantee cost recovery since the receipt depends directly on the consumed volume. In order to prevent the risk of not covering costs (and especially fixed costs linked to infrastructures; see for example Iglesias and Blanco, 2008, ) a two part tariff may be chosen: besides the volumetric pricing, a fixed price is applied to water users. This fixed price will guarantee a minimum regular income ensuring the water provider a part of its cost recovery.

The volumetric part can be priced in three main ways. It can be either constant whatever the level of consumed water or priced "per block": the cost per additional consumed unit varies when the level of consumption reaches some given thresholds. The marginal pricing can either increase with the level of consumption (increasing block tariff) or decrease (declining block rate).

The increasing block tariffs (IBT) can be used to impose conservation incentives on some target group of large users. Customers facing the higher prices at the margin will, in theory, use less water than they would under the uniform pricing; customers facing lower prices at the margin will use more. The increasing block design will conserve water if the sum of decreases in use exceeds the sum of increases. The expectation is that demand in the high blocks will be more elastic than demand in the low blocks, resulting in a net decrease in water use. Although there is widespread consensus that IBT have many advantages, this type of tariff still deserves more careful examination since an incorrect structure of the IBTs leads to several shortcomings as argued by Boland and Whittington (2000), such as difficulties to set the initial block, mismatch between prices and marginal costs, conflict between revenue sufficiency and economic efficiency, absence of simplicity, transparency and implementation, incapacity of solving shared connections, etc.

The decreasing block tariff (DBT) is, unlike the preceding one, in accordance with the proposition that high value goods “should” be bought at higher price than low value goods. Water will be first purchased for uses with high values, and then only for uses which will lead to less welfare increases. Concerning equity, this type of tariff is “not advisable”. “The consumers who acquire smaller amounts of the good and/or service because of their low incomes would be bearing a higher price than those who can afford to consume greater amounts” (Gracia and al., 2001). But it can be justified in the following circumstances:

- When users have very different levels of consumption. A consumer hundred times bigger than the average consumer does not create costs hundred times higher, because there is only one pipe line, one billing process. . . And, since cost per volume is lower with large consumers, it is justifiable to propose DBT in case of heterogeneous users.

- In order to incite users to stay in the WUA: as we have explained above, IBT might encourage users who have access to alternative water sources to quit (partly at least) the network, stopping to contribute to the recovery of the costs. This can lead to cost recovery problems for the water supplier and besides might lead to negative environmental consequences. DBT does not have this negative incentive.

A two-part tariff combines a fixed and a volumetric rate (or a mix of fixed and variable elements). “Under this system, consumers must pay an entry charge that entitles them to consume the good. Subsequently they will pay an additional smaller amount for each extra unit consumed [in the case of a DBT for the volumetric part].” “Two part tariff are easy to explain and

easy to understand.” (Gracia and al., 2001). But in practice it fails to reach the efficiency objective and suffer from the fact that it does not allow to reveal information on water demand, which may be at the origin of sudden discrepancy between water supply and demand.

In the following we study the properties of a different pricing structure, in which each farmer makes a water reservation, say in spring, before planting, and then pay a water bill which is an increasing function of his/her reservation and of his/her consumption. This allows the water user manager to forecast a disequilibrium between water demand and supply. The water pricing is parameterized (parameters  $a$ ,  $b$  and  $\lambda$ ), in order to adapt the price to the actual WUA situation and to the available water supply. Section 2 we present the notations, the pricing formula and its first properties. In section 3 we study the optimal farmer’s behaviour. In section 4 we conclude with some considerations on further researches.

The different qualities of this pricing structure, that we study here with a simple deterministic model, are in accordance with the four aims of the WUA manager we presented before, even the ease to be understood when for example the pricing formula is translated in a double entry table. Therefore it compares favorably to the other previously presented classical water pricing methods.

## 2 The model

### 2.1 Notations

We consider a water user association, composed of  $n$  farmers, which provides them irrigation water at a cost. Each farmer  $i$  has a production function we note  $h_i(C_i)$ , function of the volume  $C_i$  of the water he consumes. This production function is private information, known only by the farmer himself.

Each year, each farmer firstly reserves a water volume  $S_i$ , for example before choosing his planting, then consumes another volume  $C_i$  for the field irrigation,  $C_i$  being either inferior or superior to  $S_i$ . The pricing formula is designed in order to take into account these two variables and to display some properties.

The notation we use are the following:

- $B$  is the total water user association expenses
- $D$  is proportional to  $B$  :  $D = \lambda B$ , with a constant  $\lambda > 0$ ,
- $S_i$  is the volume reserved by agent  $i$  during the considered year,
- $C_i$  is the volume consumed by agent  $i$  during the same year,
- $F_i$  is the sum agent  $i$  must pay (his water bill).

For each agent  $i$ , the pricing formula is:

$$F_i(S_i, C_i) = D \left( a S_i + (1 - a) \frac{\max(C_i, b S_i) C_i}{S_i} \right), \quad (1)$$

with  $a \in (0, 1)$  and  $b \in (0, 1)$ .

The pricing scheme is common knowledge for all farmers, and is the same for all of them. Parameter  $a$  represent a kind of sharing of the price between on the first hand the reservation part and on the other hand the consumption part. The role of parameter  $b$  is to incite to reserve at least the forecasted consumption divided by  $b$ . When  $C_i > bS_i$ , the  $C_i^2$  which appears in the pricing formula incites to diminish water consumption.

We show here that a deterministic approach, without acquisition of information between the reservation date and the consumption date, is sufficient in order to study some of the properties of this pricing. Of course other properties directly linked to stochastic variables (as the climate) cannot be studied here and are the object of further researches.

## 2.2 Preliminary properties of the pricing formula

We study the properties of this formula in the following way: Once  $C_i$  is known, and therefore the gross product of the field is given, the objective of the farmer is to minimize his water bill, by choosing judiciously his reserved volume. This allows to compute a function  $S_i(C_i)$  with which we can calculate the optimal volume the farmer use for irrigation, knowing that each different choice of  $C_i$  leads to some harvest  $h_i(C_i)$  and to a minimal water bill.

If  $C_i$  is given, the objective of  $i$  is to minimize in  $S_i$ :

$$F_i(S_i, C_i) = \begin{cases} D \left( a S_i + (1 - a) \frac{C_i^2}{S_i} \right) & \text{if } b S_i \leq C_i, \\ D (a S_i + (1 - a) b C_i) & \text{if } b S_i > C_i. \end{cases}$$

We can deduce the following properties of this pricing scheme:

- $F_i(S_i, C_i)$  is a continuous function in  $S_i$ .

- $$\frac{\partial F_i(S_i, C_i)}{\partial S_i} = \begin{cases} D \left( a - (1-a) \left( \frac{C_i}{S_i} \right)^2 \right) & \text{if } b S_i < C_i, \\ a D & \text{if } b S_i > C_i. \end{cases}$$

and it is not defined in  $b S_i = C_i$ .

- $$\frac{\partial F_i(S_i, C_i)}{\partial S_i} = 0 \iff S_i = \sqrt{\frac{1-a}{a}} C_i, \text{ and } b \sqrt{\frac{1-a}{a}} < 1.$$

These properties imply the following result:

**Lemma 1** *The minimization of (1) in  $S_i$ , for  $C_i$  given, is:*

$$S_i^* = \sqrt{\frac{1-a}{a}} C_i \quad \text{if } \frac{b^2}{b^2+1} < a < 1,$$

$$S_i^* = b^{-1} C_i \quad \text{if } 0 < a \leq \frac{b^2}{b^2+1}.$$

Note that we obtain a linear relation between  $S_i$  as a function of  $C_i$ , that depends only on the parameters  $a$  and  $b$ .

### 3 The maximization problem of farmer $i$

When choosing the values of his control variables  $S_i$  and  $C_i$  the farmer must decide of the optimal value of  $C_i$  knowing the optimal value of  $S_i$  previously announced. Therefore each farmer must solve:

$$\max_{S_i} \left[ \max_{C_i} (h_i(C_i) - F(S_i, C_i)) \right], \quad (2)$$

where, the profit function of farmer  $i$ ,  $h_i$ , is an increasing and concave function.

### 3.1 The maximization problem in $C_i$

We note  $G(S_i, C_i) = h_i(C_i) - F(S_i, C_i)$  (see Fig. 1). We have then:

$$\frac{\partial G_i(S_i, C_i)}{\partial C_i} = \begin{cases} h'_i(C_i) - 2(1-a)D\frac{C_i}{S_i} & \text{if } bS_i < C_i, \\ h'_i(C_i) - (1-a)bD & \text{if } bS_i > C_i. \end{cases}$$

We note,  $C_i^-(S_i)$  the solution in  $C_i$  of

$$h'_i(C_i) = 2(1-a)D\frac{C_i}{S_i},$$

With a simple derivation of this last equation, it is easy to see that

$$C_i^{-'}(S_i) = \frac{2(1-a)DC_i}{2(1-a)DS_i - h''(C_i)S_i^2} > 0,$$

therefore,  $C_i^-(S_i)$  is an increasing function of  $S_i$ .

We call  $C_i^+$  the solution in  $C_i$  of (note that this solution does not depend on  $S_i$ ):

$$h'_i(C_i) = (1-a)bD.$$

When  $bS_i < C_i$  we have:

$$2(1-a)D\frac{C_i}{S_i} > 2(1-a)bD > (1-a)bD,$$

The concavity of  $h_i$  implies that

$$C_i^-(S_i) < C_i^+.$$

We can easily deduce that the optimal solution  $C_i^{sol}$  of (2) for  $S_i$  given depends on the relative positions of  $C_i^-(S_i) < C_i^+$  and of  $bS_i$ :

$$C_i^{sol} = \begin{cases} C_i^-(S_i) & \text{if } S_i < C_i^-(S_i)/b, \\ bS_i & \text{if } C_i^-(S_i)/b \leq S_i \leq C_i^+/b \\ C_i^+ & \text{if } S_i > C_i^+/b. \end{cases}$$

Note that this formula gives a relation  $C_i^{sol}(S_i)$  that depends on the parameters of the regulator and the profit function of farmer  $i$ .  $C_i^{sol}(S_i)$  is first an

increasing function, then linear and finally a constant.

### Maximization in $C_i$ : a numerical example

If  $h(C_i) = \frac{C_i^\alpha}{\alpha}$ , the maximization problem for  $S_i$  given is:

$$C_i^{sol} = \begin{cases} (2(1-a)D)^{\frac{-1}{2-\alpha}} S_i^{\frac{1}{2-\alpha}} & \text{if } S_i < \frac{(2(1-a)D)^{\frac{-1}{1-\alpha}}}{b^{\frac{1}{1-\alpha}}}, \\ b \cdot S_i & \text{if } \frac{(2(1-a)D)^{\frac{-1}{2-\alpha}}}{b^{\frac{1}{1-\alpha}}} \leq S_i \leq \frac{((1-a)bD)^{\frac{-1}{1-\alpha}}}{b}, \\ ((1-a)bD)^{\frac{-1}{1-\alpha}} & \text{if } S_i > \frac{((1-a)bD)^{\frac{-1}{1-\alpha}}}{b}. \end{cases}$$

Taking now  $\alpha = 0.5$ ,  $a = 1/3$ ,  $b = 0.7$ ,  $D = 2$ , the numerical values are:

$$C_i^{sol} = \begin{cases} \left(\frac{3}{8}\right)^{2/3} S_i^{2/3} & \text{if } S_i < \left(\frac{3}{8}\right)^2 \left(\frac{10}{7}\right)^3, \\ 0.7 S_i & \text{if } \left(\frac{3}{8}\right)^2 \left(\frac{10}{7}\right)^3 \leq S_i \leq \left(\frac{30}{28}\right)^2 \frac{10}{7}, \\ \left(\frac{30}{28}\right)^2 & \text{if } S_i > \left(\frac{30}{28}\right)^2 \frac{10}{7}. \end{cases}$$

We see in Fig. 2 how the optimal consumption  $C_i^{sol}$  depends on the value of  $S_i$  and  $\alpha$ .

### 3.2 The maximization problem in $S_i$

When solving the maximization of our problem in  $S_i$ , knowing the optimal value  $C_i$ , (which is generally a function of  $S_i$ ), we must consider the relation between  $S_i$  and  $C_i$ .

- if  $S_i < C_i^-(S_i)/b$  we must solve

$$\max_{S_i} (h_i(C_i^-(S_i)) - F(S_i, C_i^-(S_i))),$$

and the first order condition gives:

$$h'_i(C_i^-(S_i)) C'^{-}_i(S_i) = D \left[ a + (1-a) \frac{2C_i^-(S_i)C'^{-}_i(S_i)S_i - (C_i^-(S_i))^2}{S_i^2} \right]. \quad (3)$$

- if  $C_i^-(S_i)/b \leq S_i \leq C_i^+/b$  we get

$$\max_{S_i} (h_i(bS_i) - D(aS_i + (1-a)b^2S_i)),$$

with first order condition:

$$bh'_i(bS_i) = D [a + (1-a)b^2]. \quad (4)$$

- and if  $S_i > C_i^+/b$  the maximization problem is then

$$\max_{S_i} (h_i(C_i^+) - F(S_i, C_i^+)),$$

that does not have a solution.

To obtain the optimal solution of our problem in  $S_i$  we must analyze the admissibility of solutions of (3) and (4). We can assure that the optimal solution of (2) is such that  $bS_i \leq C_i$ .

To do that we have the following result:

**Lemma 2**

$$\max_{S_i} \left[ \max_{C_i} (h(C_i) - F(S_i, C_i)) \right] = \max_{S_i, C_i} [h(C_i) - F(S_i, C_i)]. \quad (5)$$

**Proof.**

In section 3.1. of this paper we have shown that the solution of

$$\max_{S_i} \left[ \max_{C_i} (h(C_i) - F(S_i, C_i)) \right], \quad (6)$$

is given either if  $bS_i = C_i$  (border solution) by the maximization in  $S_i$  of  $G(S_i, bS_i)$  or if  $bS_i < C_i$  (interior solution) by

$$h'(C_i) = 2(1-a)D \frac{C_i}{S_i}, \quad (7)$$

with

$$h'(C_i^-(S_i)) C_i^-(S_i) = D \left[ a + (1-a) \frac{2C_i^-(S_i)C_i'^-(S_i)S_i - (C_i^-(S_i))^2}{S_i^2} \right]. \quad (8)$$

Now if we solve the problem

$$\max_{S_i, C_i} (h(C_i) - F(S_i, C_i)), \quad (9)$$

its interior solution (with  $bS_i < C_i$ ), knowing from section 2.2 that

$$\frac{\partial G(S_i, C_i)}{\partial S_i} = 0 \iff S_i = \sqrt{\frac{1-a}{a}} C_i \text{ and } b \sqrt{\frac{1-a}{a}} < 1, \quad (10)$$

is given by

$$\frac{\partial G(S_i, C_i)}{\partial C_i} = 0 \iff h'(C_i) = 2(1-a) D \frac{C_i}{S_i},$$

which coincides with (7). Replacing this equation in (3) we obtain

$$2(1-a)D \frac{C_i}{S_i} C_i' = D \left( a + \frac{(1-a)2C_i C_i'}{S_i} - (1-a) \frac{C_i^2}{S_i^2} \right).$$

Simplifying we find equation (10) so that the interior solution coincides with the solution of (2). The border solutions are also the same (i.e.  $bS_i = C_i$ ) for (2) and for

$$\max_{S_i} \left[ \max_{C_i} (h(C_i) - F(S_i, C_i)) \right]. \quad (11)$$

Finally both solutions are the same. ■

From Lemma 1 and Lemma 2 we can deduce that

**Theorem 1** *The optimal strategie of farmer  $i$  is:*

*i)  $S_i = C_i \sqrt{(1-a)/a}$  if  $b^2/(1+b^2) < a < 1$  where  $C_i$  is the solution of*

$$h_i'(C_i) = 2D\sqrt{a(1-a)}. \quad (12)$$

*ii)  $bS_i = C_i$  if  $0 < a \leq b^2/(1+b^2)$  where  $C_i$  is the solution of*

$$h_i'(C_i) = \frac{D(a + (1-a)b^2)}{b}. \quad (13)$$

**Remark 1**

*The optimal solution is a continuous function of the parameters  $a$  and  $b$ .*

*The regulator can choose the parameters  $a$  and  $b$  in order to enforce an interior solution or a border solution.*

**Remark 2** *Note that in ii) of last theorem*

$$\lim_{b \rightarrow 0} \frac{D(a + (1-a)b^2)}{b} = \infty.$$

If we choose  $b$  small enough and therefore  $a$  small enough to remain in case ii), (13) incites the farmers to use less water, i.e.  $C_i \rightarrow 0$  when  $b \rightarrow 0$ . But in general we can not draw any conclusion on the value of  $S_i$ . Nevertheless in the previous exemple with  $h_i(C_i) = C_i^{\alpha_i}/\alpha_i$ , we have

$$S_i = \frac{1}{D(a + (1 - a)b^2)^{\frac{1}{1-\alpha_i}}} b^{\frac{\alpha_i}{1-\alpha_i}},$$

and we conclude that  $S_i \rightarrow 0$  too when  $b \rightarrow 0$ . In conclusion the manager may use these two parameters  $a$  and  $b$  in order to decrease the water consumption but he can not make water decrease at discretion since as in our exemple he might decrease also the reserved volume and at the end the budget equilibrium would not be satisfied.

Note also that in i) of last theorem, we can not make the consumption  $C_i$  decrease at will, since the maximum value of  $h'_i(C_i)$  is equal to  $D$  according to (13).

In conclusion the manager by the choice of parameters  $a$ ,  $b$  and  $\lambda$  leads the problem either in case i) for which a budget equilibrium can be attained or in case ii) where he incites the farmers to lessen his water consumption<sup>1</sup> while possibly allowing a budget equilibrium. The budget equilibrium will be studied in more details in next section.

### 3.3 The budget equilibrium constraint

In this section we study the conditions in which the budget equilibrium may be obtained, or in other terms, in which

$$\sum_i F_i(S_i, C_i) = B. \quad (14)$$

The water user association may choose the parameters  $a$  and  $b$  in such a way that:

i) either  $b^2/(1 + b^2) < a < 1$  and then  $S_i = C_i \sqrt{(1 - a)/a}$ ,

$$C_i = [h'_i]^{-1} (2D \sqrt{a(1 - a)}) =: g_i(2D \sqrt{a(1 - a)}),$$

and the budget equilibrium constraint (14) must be written as:

$$2\lambda B \sqrt{(1 - a)/a} \sum_i C_i = 2\lambda B \sqrt{(1 - a)/a} \sum_i g_i(2\lambda B \sqrt{a(1 - a)}) = B.$$

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<sup>1</sup>since  $D \leq h'_i \leq \infty$  in ii) and  $0 \leq h'_i \leq D$  in i) the water consumption is always inferior when in ii) than when in i).

That is:

$$2\lambda\sqrt{(1-a)/a} \sum_i g_i(2\lambda B\sqrt{a(1-a)}) = 1.$$

When  $h_i(C_i) = \frac{C_i^{\alpha_i}}{\alpha_i}$ , this last equation becomes

$$f(\lambda) = 2\sqrt{(1-a)/a} \sum_i \lambda^{\frac{\alpha_i}{\alpha_i-1}} M_i = 1, \quad (15)$$

where

$$M_i = (2B\sqrt{a(1-a)})^{1/(\alpha_i-1)}.$$

Noting that  $f(0) = +\infty$ , that  $\lim_{\lambda \rightarrow \infty} f(\lambda) = 0$  and that  $f'(\lambda) < 0$ , we deduce that there exists a unique  $\lambda$  which verifies (15).

ii) or  $0 < a < b^2/(1+b^2)$  and then  $S_i = bC_i$ , in this case,

$$f(\lambda) = A \sum_i \lambda^{\frac{\alpha_i}{\alpha_i-1}} M_i = 1,$$

where

$$A = \frac{D(a + (1-a)b^2)}{b}, \quad M_i = (BA)^{1/(\alpha_i-1)},$$

and we obtain the same conclusion as in i).

So, once the parameters  $a$  and  $b$  are chosen for considerations of water savings, the water user association manager can force the system to be in budgetary equilibrium with the choice of the parameter  $\lambda$  value. Of course, not knowing the true value of the  $\alpha_i$  parameters, or more generally of the  $h_i(C_i)$  functions, he will not be able to compute directly the optimal  $\lambda$  value, but the existence result on a unique  $\lambda$  value and the monotonicity of  $f(\lambda)$  allow him to find the correct value by fumbling.

## 4 Conclusion

We have shown here how it is possible with a pricing system based on two variables, reservation and consumption, for the Water User Association manager to get enough information in order to anticipate any disequilibrium between water demand and supply, when it is always possible to change the choice of the cultures. Moreover changing the parameters allows him to modify the volume consumed by the farmers, which is especially useful when searching a decrease of the water consumption. Translated in a two entry table, this method is simple to understand by each farmer, and quite acceptable since associating the pursuit of fairness, efficiency and adaptability.

At last, with a judicious choice of the value for the parameters, it is possible to incite the farmers to be more or less acute in the choice of their reservation and consumption values. This pricing system should therefore allow a more efficient use of the water resource by the farmers, by the way decreasing the constraints on other economic sectors and on the environment. Further researches are nevertheless needed to study how such a system keeps or increases its advantages when we take into account the fact that in many countries the water supply may be stochastic. Moreover the information acquisition may be sequential, throughout spring and summer seasons in most places. This leads to other refinements which are the aim of other present researches.

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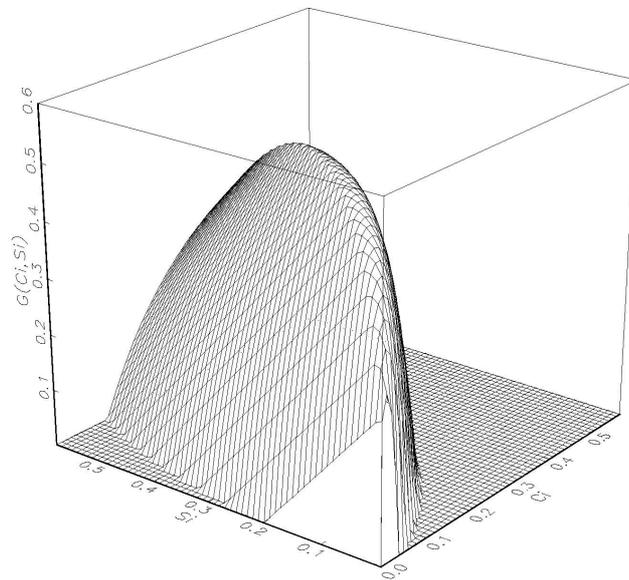


Figure 1:  $G(S_i, C_i)$

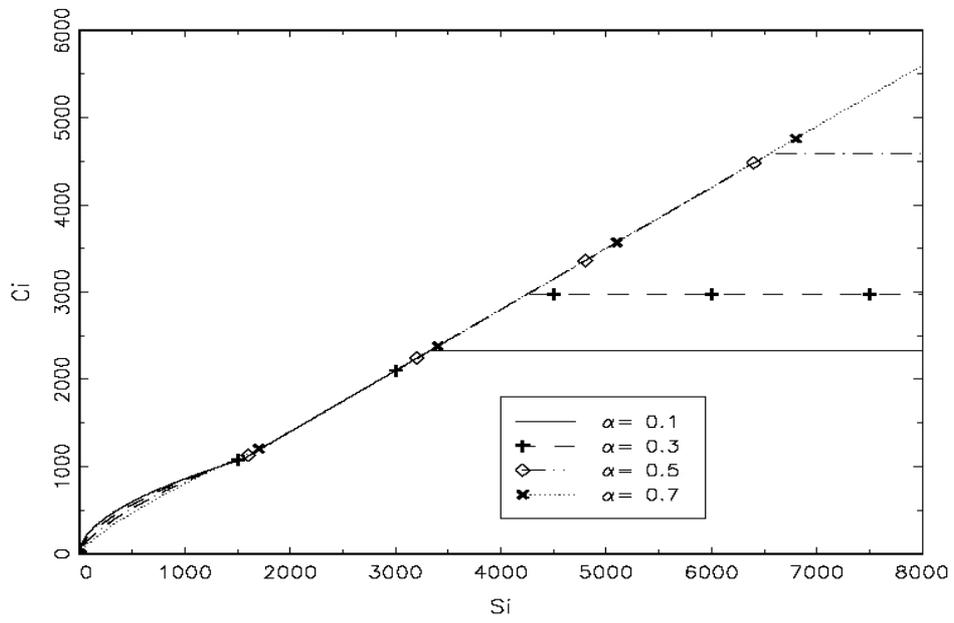


Figure 2: Optimal policy  $C^{sol}(S_i)$

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