An economic model for water allocation in North Eastern Spain

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AN ECONOMIC MODEL FOR WATER ALLOCATION IN NORTH-EASTERN SPAIN♦

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ABSTRACT

The aim of this paper is to construct and apply a model for the allocation of water between two competing users, namely irrigation and hydropower. The model is applied in a case study of a specific water system located in North Eastern Spain. Starting with an irrigation-hydropower joint income function, we develop a constrained maximisation process that takes into account the environmental, institutional and actual priority of the water rights. The resulting solution can be useful as a guide for potential bargains between users. Furthermore, we evaluate the results for different supply (precipitation) and water allotments (increase in irrigated land). The results show that there are sufficient incentives so as to reach agreements that lead to improvements in a Pareto sense without side payments.

Keywords: Environmental and Natural Resource Economics, Water Economics, Bargaining, Cooperative Games.

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1. Introduction

The problems faced by the management of water in countries where the Mediterranean climate prevails are well known, given the uncertainty to which the supply of this resource is subject both in terms of space and over time. In order to guarantee that users can rely on the necessary amounts of surface water, certain volumes and priorities are assigned to the different uses under the terms of the so-called water rights, with these representing the main legal instrument that ranks and allocates the uses in space and over time.

The two most important elements that define the water right from the point of view of the short-term management of the resource are the volume and the guarantee. Although these are, in principle, two different aspects -the volume of needs as against the security level- they have traditionally been considered as one and the same problem, in such a way that the level of use granted in the water right is over and above that which is strictly necessary. The deliberate over-scaling of civil engineering projects for the regulation of water (generally financed by way of public funds) have frequently been used in order to guarantee that the true needs are satisfied even in dry years.

Against this background, the literature and, to a lesser extent, empirical practice has considered the possibility of water rights transactions under a formula that is more or less the same as that which would operate in a free market of such rights. As Sumpsi et al. (1998) indicate, these mechanisms are cheaper and, above all, more flexible strategies than water regulation projects, in that the associated environmental costs are lower or, at the very least, would not generate situations of irreversibility. Illustrations of this approach can also be found in Garrido (1994) and the now classic texts of Young and Haveman (1985) and Gibbons (1986). On the adequacy of specific situations to market models and the problems this entails, see Colby et al. (1993) or Griffin and Hsu (1993) amongst others..

However, and as Winpenny (1994) confirms, the heart of the process for the allocation of large volumes of water continues to be governed by a body of administrative regulations, with the free exchange of water rights being exceptional. Thus, the search for allocation schemes that are closer to the market and in a basic context of the public ownership and distribution of the water resource remains a fruitful field of research. An example of this at the international level can be found in the work of Dinar and Wolf (1994). Two basic aspects that must be reflected in such allocation schemes are the order of priority of the water rights established by law and, as already mentioned, the uncertainty to which the supply of water is subject in the Mediterranean lands, and particular attention is given to these in what follows.

The central problem that we address is the conflict between different users of the water resource. This conflict arises from either restrictions in the supply or increases in the requirement as a result, for example, of a decline in precipitation or of greater water requirements to irrigate new areas. In this paper, such a problem and the possibilities of its resolution are considered in a very habitual case, namely competition between irrigation and hydropower for the use of water stored in a reservoir. The technical antecedents for such a situation can be found in Butcher and Wandschneider (1986) and Houston and Whittesey (1986). Similarly, we can cite antecedents that are geographically close to our case study, as reflected in the so-called "Pacto de Piñana" (Piñana Agreement), where the right to freely turbine the waters of the Santa Ana reservoir, lying on the river Noguera Ribagorzana, whose water rights were previously owned by the hydropower companies, where negotiated away in exchange for a significant monetary compensation (see Bielsa, 1999).

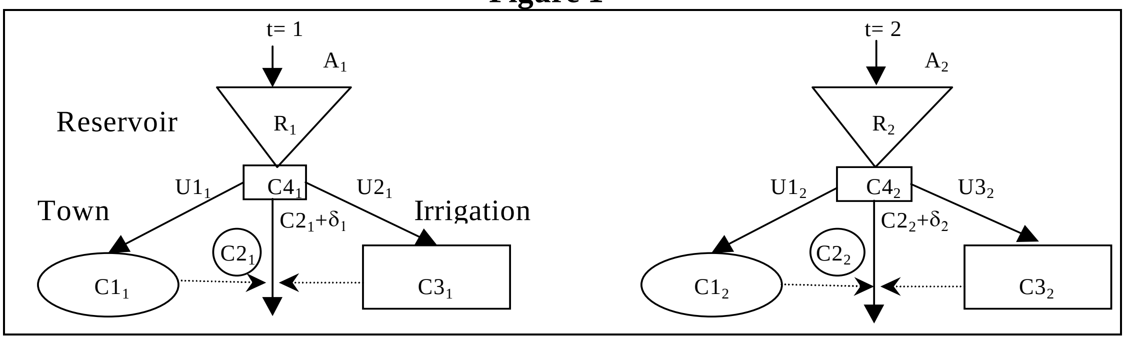
The rest of the paper is organised as follows. In Section 2 we introduce the theoretical model to represent this type of problem. This model includes the specification of the two users in the behaviour functions and, as its most novel aspect, the formal representation of the priority in the uses resulting from the application of the legal regulations through the constraints of the problem. On the basis of a constrained maximisation model, we consider bargaining between the parties in order to reach, if possible, a greater overall profit in a cooperative agreement. Section 3 is devoted to an empirical application of the model through the simulation of various scenarios and Section 4 closes the paper with a review of the main results.

2. The Model

A first theoretical principle in any analysis of this water problem undertaken from the point of view of economic theory is that users will exchange units of resource up to the point when the value of the marginal productivity of the last units of water incorporated coincides in each one of these users (the principle of equimarginality). In the particular case of water, to achieve this optimum situation, particular account must be taken of the institutional framework in which the users' decisions are taken (order of priority of the uses established by law and volume assigned that defines its water right). Thus, on the basis of an inefficient allocation, and to the extent that the institutional framework permits, the exchange of rights should lead us, if not to a theoretical equilibrium, then at least to a better situation in the Pareto sense. To guarantee the move to a new distribution of resources, side payments will occasionally be necessary in favour of the parties that assign their rights. This consideration will be equal to the difference between their level of profits before and after the transaction, according to the Kaldor-Hicks principle of compensation.

Resting on this well known theoretical framework, the model we propose describes the joint profit function of the two agents (irrigation and hydropower). It also reflects the system of water flows that result from the interaction between four types of use with different water rights regimes in a territory that counts on a river channel and a reservoir that mitigates markedly seasonal nature of the precipitation. The uses are linked one with the other both by their geographical situation and by the order of priorities established by law. The geographical structure that determines the relationship between the uses appears in Figure 1.

Figure 1



We divide the water year into the non-irrigation ($t = 1$) and irrigation ($t = 2$) periods and we have four water users: urban (U1), the minimum streamflow or compensation flow (U2), irrigation (U3) and hydropower (U4). The levels of water rights and effective use are Ck_t, Uk_t for k = 1,2,3,4, types of use. The reservoir that supplies them has certain minimum levels to guarantee drinking water, which we denote by R^0.

The term δ_t, that can be positive or negative, represents the possible surpluses/deficits that arise with respect to the minimum streamflow $C4_t$. The stock variables of the model are Vt and Rt. Vt represents the volume of water available in each system and corresponds to the initial reserves of that system (R_{t-1}) plus the streamflows it receives in the form of upstream flows of the river (A_t). The variable Rjt takes values between 0 and the maximum capacity of the reservoir (R^{max}).

Furthermore, in function of what is the amount of streamflows and the intensity of the uses, the volume of reservoir reserves will take values above or below the security reservoir reserve R^0. Thus, if the available water is insufficient even for urban uses, the reserve will be null until such uses are satisfied and, from that moment on, will have priority over any other use until the said security level is reached ($R_t = R^0$). Once this limit has been exceeded, additional units of water will only be stored in the reservoir if all other uses have been satisfied.

The irrigation-based farmers cultivate a mixture of *i* different products (i = 1,2,...,n) with profits per unit of surface area (also discounting the cost of water. Note that the margin used corresponds to the profit per hectare; that is to say, to the net margin less other indirect costs as these are defined in the agricultural accounting documents, for example, MOPTMA (1993).) of $m^A{}_i$, surface areas given over to cultivation of s_i and water use for each crop and period of $U3_{it}$ (which, in turn, depends on the water requirements of the crop, WR_i and the irrigation efficiency, e).

As regards hydropower, the profit also depends on its profit per unit of energy produced (m^H), on the turbined streamflow ($U4_t$), on the feet of head of water in the reservoir (h) -which, in turn, depends on the volume of water stored in the reservoir h = h (R_t)- and on a conversion constant of these factors in energy that we note as α . The margin m^H corresponds to the profit obtained by the last unit of energy (Kwh) produced.

On the basis of this general scheme, we propose an optimum allocation model between uses with the following objective joint profit function and constraints:

$$\text{Max M} = \sum_{t=1}^{2}\sum_{i=1}^{n} m_i^A \, s_i U3_{it}(WR_i ; e_i) + m^H \alpha \sum_{t=1}^{2} h(R_t)\, U4_t$$

subject to:

$$V_t = R_{t-1} + A_t \quad (1)$$

$$R_t = Min\left\{R^{max}; Max\left[V_t - Max(C1_t; C3_t + C2_t + C4_t); Min(R^0; V_t - U3_t)\right]\right\} \quad (2)$$

$$U1_t = Min\{C1_t; V_t\} \quad (3)$$

$$U2_t = Min\{C2_t; V_t - U1_t - R_t\} \quad (4)$$

$$U3_t = Min\{C3_t; V_t - U1_t - R_{jt} - U2_{jt}\} \quad (5)$$

$$U4_t = Min\{C4_t; V_t - R_t\} \quad (6)$$

The constraints reflect three essential aspects. First, the order of priority of the water rights. Secondly, the relation between uses (rival and successive, that is to say, that compete for the same unit of water or that use the water successively). Thirdly, the fact that the water right is the maximum level of water that can be used by each agent.

As regards the order of priority, this has been established in legal form in the following terms. First, urban requirements of the two systems (in the case of extreme scarcity, priority will be given to the use that is closest to the upper stretches of the river) and the security reservoir reserves. Second, the minimum streamflow ($U2_t$), third, irrigation requirements ($U3_t$) and fourth, the hydropower requirements ($U4_t$). This explains the succession of nested constraints according to the order of priority.

Turning to the second of these aspects, the relation between uses, the hydroelectric plant uses and the minimum streamflow are successive because the turbining is carried out at the foot of the reservoir. However, the urban and the irrigation water uses of each system are rivals one with the other and with respect to the other uses, that is to say, the water diverted for these purposes is not available in the river channel (save that which subsequently comes back to it via return flows). Thus, if we calculate the total requirement of two rival uses, we will do so by totalling them and, if they are successive, by selecting the larger of them. Finally, no user can exceed the volume of water granted or bargained under the terms of its water right, which justifies the minimum option in the constraints of the uses and of the levels of reserves.

As a consequence of the above, if there is a balance between the median streamflows and the water required for the systems of uses, then the six constraints will allow us to see how the water is assigned to each type of use, thereby characterising a steady equilibrium between resources and requirements.

Having established the theoretical framework, we will now carry out a comparative static exercise on the basis of a specific case comprised of the following steps. First, we assume a reduction in the streamflows (dry years) that leads to a conflict between uses. We then consider and solve the constraint maximisation problem for these new values of the exogenous variables. Finally, we evaluate and compare the two situations, that is to say, that which results from the strict application of the order of priorities and that obtained from the joint profit optimisation exercise, in relation to the conflict as initially posed.

3. Empirical Application

To illustrate the essential aspects of the proposed model, in this Section we will apply it to an analysis on the rival requirements for the water stored in the Vadiello reservoir, which lies in the province of Huesca in North Eastern Spain. This area is characterised by its well delimited urban (the city of Huesca) and irrigation (1400 Ha. of irrigated land) requirements, as well as by the minimum streamflow (of an amount similar to that for urban use) and the possible need for water by a hypothetical hydroelectric plant. We have also defined a security reservoir reserve for urban use of 5 Hm^3 from a reservoir that has a capacity of 16 Hm^3.

Table 1 represents a situation that we might describe as steady equilibrium for a given regime of streamflows (that of the Vadiello reservoir in an average water year).

As we can see, all the water rights are satisfied, that is to say, there is no deficit for any sector. The net requirement shows the volume of water withdrawn from the reservoir to meet the uses. Given that the value of turbined water depends on the feet of head of water held in the reservoir at any moment (and, therefore, on the volume of reserves), each one of the periods is associated with a value of energy per unit of water used, which in this case is of 0.32 pesetas/m^3 in the two periods.

Table 1

	T1	T2		T1	T2

Streamflow	20	12	*Net Demand*	12	20
Available	25	27	*Initial Reserves*	5	13
C1	10	10	*Final Reserves*	13	5
C2	0	12	*Deficit*		
C3	4	4	*1 Úrban*	0	0
C4	4	4	*2 Min Stflow*	-4	0
U1	10	10	*3Irrigation*	0	0
U2	0	12	*4 Hydropower*	0	0
U3	4	4	*Security reserve.*	0	0
U4	4	4	*H'power profit*	0.32	0.32

3.1 A study of the possible strategies and scenarios

Starting from a situation of equilibrium such as that described earlier, we can pose two types of problem that can arise as a result of changes in the conditions of supply and/or requirement. The first is of drought, where we suppose a fall in streamflows of 30%, whilst the second involves an increase in the surface area given over to irrigation of 500 new hectares.

We reduce both problems to the following terms: calculate the changes in the turbining programme that are necessary in order to maximise the joint irrigation-hydropower profit. The resolution of this problem determines certain levels of water stored in the reservoir (R_t) in the first period (immediately prior to the beginning of the irrigation season) and certain changes in the profits of both uses in the face of this new situation. In the circumstances where losses are suffered in the hydropower sector with respect to the initial situation, it will be necessary to evaluate them and to establish some bargaining system that guarantees that this new equilibrium is achieved and accepted by both parties.

In order to make the theoretical model operative, we make the profit function take a specific form in such a way that m^H is a standard value of the electric energy of 8 pesetas/Kwh (updated value of the margin for hydropower production that appears in MOPTMA (1993)) the feet of head is estimated by way of a function $h = \beta \ln(R')$ (where R' represents the average reservoir reserves between the two periods). The best fit to the head of the reservoir and the reserves is obtained through a semi-logarithmic function with coefficient 8.2323. The parameter α in the maximisation function is the flow conversion constant and feet of head in energy with a turbining return of 80% that takes the value of 2180 Kwh/Hm^3.

For its part, the 1400 hectares of irrigation that exist in the area are distributed between four types of crop: cereals (55%), industrial crops (29%), vegetables (15%) and fruit (1%). We assume in all cases irrigation efficiency of 47% (see Bielsa, 1999). In what follows we will consider both cases and the strategies associated with them.

3.2. Case 1: Strategy in a dry period

Here we will consider the situation that arises in the case of a reduction of 30% in the streamflow, that is to say, a "typical" dry year. The streamflows follow a stochastic process characterised according to a Normal random variable with known average and variance. The typical dry year will be that that leaves "to its left" a reduced percentage of the years (for example 2.5%). This means that in no case is it considered that a guarantee of 100% is possible; the risk being simply limited to certain levels that are lower than in the absence of this stochastic view. Figures 2 and 3 show the distribution of the resources in such a situation, either with the initial water rights being maintained (non-cooperative) or when an agreement is reached between the users (optimum or cooperative solution).

The values of all the variables and parameters are reflected in Table 2. This Table is divided into three blocks: the initial seasonal situation, the case of a dry year for the initial water rights and, finally, the distribution of water rights that results from the maximisation of the joint profit. The modified values of the water right and the resultant deficits appear in bold type.

Figure 2
Non-cooperative situation in a dry year

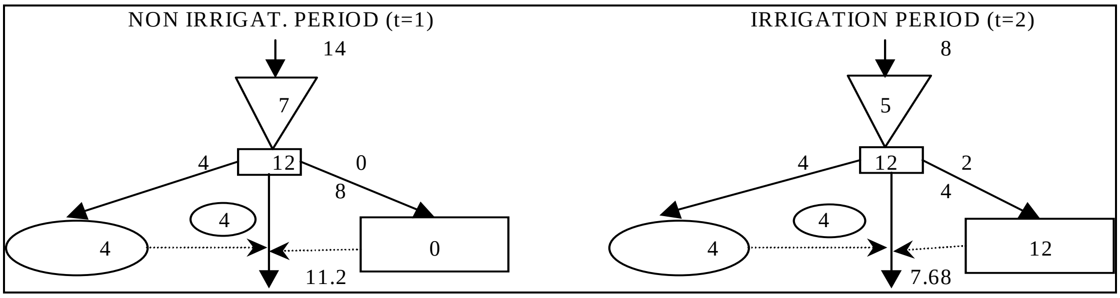
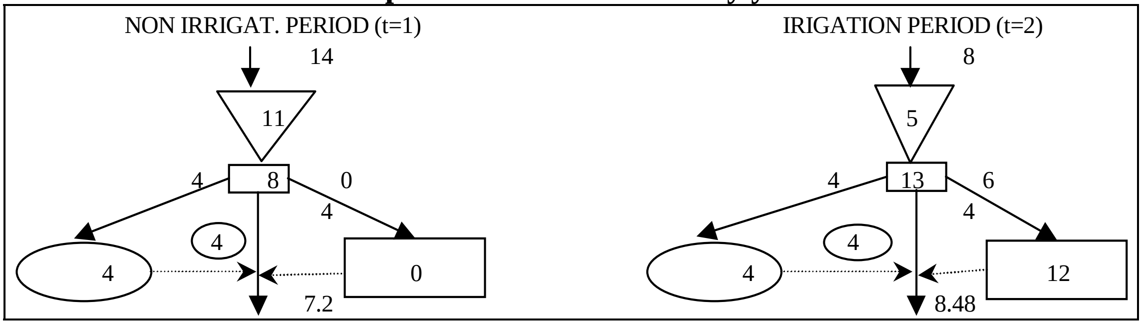


Table 2
Fall in streamflow of 30%

	Initial Situation		*Dry Year (30 %)*		*Cooperative Solution*	
	T1	T2	T1	T2	T1	T2
Streamflow	20	12	14	8	14	8
Available	25	25	19	15	19	19
C1	4	4	4	4	4	4
C2	4	4	4	4	4	4
C3	0	12	0	12	0	12
C4	12	12	12	12	**8**	**13**
U1	4	4	4	4	4	4
U2	4	4	4	4	4	4
U3	0	12	0	2	0	6
U4	12	12	12	10	8	13
Net Demand	12	20	12	10	8	14
Initial Reserves	5	13	5	7	5	11
Final Reserv. (Rt)	13	5	7	5	11	5
Déficit						
1 Urban	0	0	0	0	0	0
2 Min St'flow	**-4**	0	**-4**	0	0	0
3 Irrigation	0	0	0	**10**	0	**6**
4 Hydropower	0	0	0	**2**	**4**	**-1**
Security Reserve	0	0	0	0	0	0
Hydropower profit	0.32	0..32	0.26	0.26	0.30	0.30

Following the order of uses, the deficits appear in the second period of the dry year and, for hydropower uses, are the difference between the obligatory release of water from the reservoir for the population or the minimum streamflow (the larger of the two) and the turbining requirements of that activity. The case of irrigation, which occupies third place in the order of priority, is similar: it can count on the water left to it from urban requirements and the security reservoir reserve, with its deficit being made-up of its outstanding requirements.

Figure 3
Cooperative solution for a dry year



As we can see, the decline in precipitation is translated into a smaller amount of water stored in the reservoir that persists throughout the year. Under the optimum solution, the hydroelectric firm will change the water right programme in such a way that it renounces a part of its initial water right in the first period in exchange for a larger one in the second. This exchange further include an increase in the level of water stored in the reservoir (and, therefore, a greater head) that is translated into a higher profit per unit of water turbined (see Table 2). In this way, irrigation counts on more available resources in the dry period, which is the equivalent of a lower impact on the part of the dry period in its profit and loss account. Thus, if both parties reach an agreement such as that suggested by the optimum solution, an improvement will be achieved in the Pareto sense with respect to the case in which there is no agreement. This can be appreciated from Table 3, which shows the profits obtained from cooperation and compared to non-cooperation. We are dealing with a case of a cooperative solution that does not require side payments.

Table 3
Profits in the dry year case under cooperative and non-cooperative strategies

PROFITS*				
SECTOR	AVERAGE YEAR	NON COOPERATIVE	COOPERATIVE	GAIN
HYDROPOWER	7.62	5.80	6.25	0.46
IRRIGATION	52.29	10.46	27.89	17.43
JOINT	59.91	16.26	34.14	17.89

* The non-cooperative solution corresponds to the maintenance of the initial water rigths and the cooperative to changes in the terms indicated. The figures are expressed in millions of pesetas.

The figures show that it is possible to establish option agreements between irrigation-based farmers and hydropower producers in dry years that mitigates the irrigation losses without prejudice to the hydropower profits. This represents a type of drought insurance for irrigation, given that it is the equivalent to an increase in its effective allocation for the amount of water stored in the reservoirs when turbining is reduced.

3.3. Case 2. Increase in the irrigated surface area

In this case we suppose the existence of a plan under which the surface area being irrigated is increased by 500 hectares, without any modification to the distribution of crops. In principle, this supposes a permanent deficit of 4 Hm^3 for irrigation, given that the streamflows of an average year and the current hydropower water rights could not cover the additional requirements caused by these newly irrigated areas.

Here, we cannot speak of a meteorological deficit resulting from a decline in precipitation, but rather of an increase in requirements that exceeds the current capacity of the Water System to satisfy them. This is what the literature describes as a water deficit and, under market conditions; it can be resolved through a relative rise in the price of the good, which has become a scarce resource in such conditions. However, given the institutional structure described at the beginning of this paper, the implementation of such a process cannot be anticipated in Spain, at least in the short term.

The optimisation exercise shows that it is possible to establish agreements, that will now be of a permanent character, to improve the situation of both users. The environmental consequences of this type of transfer are a factor to be taken into account. The substitution of a source of clean energy for other alternatives could lead to permanent adverse effects on the level of CO2 or acid rain. Furthermore, these transfers could avoid the construction of new reservoirs, with the consequent benefit for the water course and the socio-economic environment of the affected areas. This balance is not taken into account in this simplified optimisation exercise, that only reflects the short-term monetary effects.

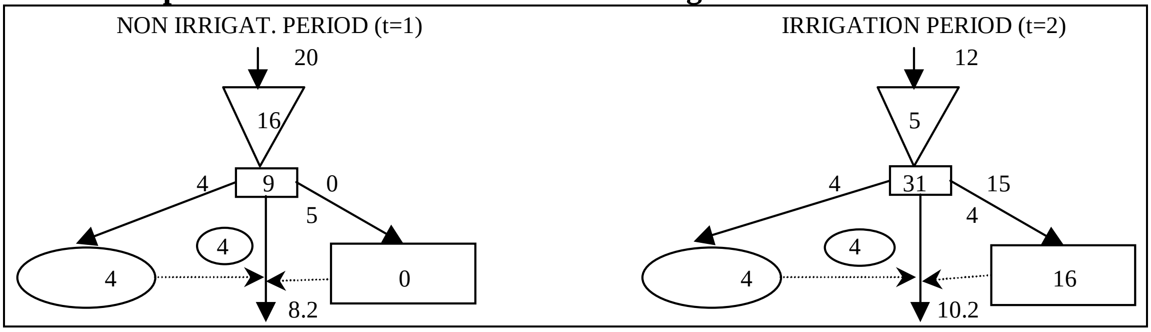
Table 4
Increase in the irrigated surface area of 500 hectares

	Initial Situation		*Non Cooperat. Solution*		*Cooperative Solution*	
	T1	T2	T1	T2	T1	T2
Streamflow	20	12	20	12	20	12
Available	25	25	25	25	25	28
C1	4	4	4	4	4	4
C2	4	4	4	4	4	4
C3	0	12	0	16	0	16
C4	12	12	12	12	9	31
U1	4	4	4	4	4	4
U2	4	4	4	4	4	4
U3	0	12	0	12	0	15
U4	12	12	12	12	9	23
Net Demand	12	20	12	20	9	23
Initial Reserves	5	13	5	13	5	16
Final Reserves(Rt)	13	5	13	5	16	5
Deficit						
1 Urban	0	0	0	0	0	0
2 Min St'flow	-4	0	-4	0	-1	0
3 Irrigation	0	0	0	4	0	1
4 Hydropower	0	0	0	0	3	-11
Security Reserve	0	0	0	0	0	0
H'power profit	0,32	0,32	0,32	0,32	0,34	0,34

Thus, we are not now faced with two different situations that we can refer to as a "normal" or "dry" year, but rather to two possible distributions of the resource over time. The following Tables and Figure illustrate the three situations of this comparative static analysis.

The agreement will take the form of hydropower renouncing 3 Hm^3 of its water right in the first period in exchange for free turbining in the second. In this way, and using the water that has been stored in the reservoir during the non-irrigation period, agriculture could have practically all the water that it needs in the irrigation period available to it.

Figure 4
Cooperative solution to the increase of irrigated surface area



Once again, the cooperative option reveals itself as being superior to the non-cooperative, given that both users will achieve an increase in their profits. Note that hydropower benefits not only from the greater volume of water turbined in the second period, but also from an increase in the value per unit of water that it uses, due to the increase in the feet of head of water stored in the reservoir. These figures and the profit obtained under the two options can be seen in Table 5.

Table 5
Profits obtained under the solution to the increase in irrigated surface area

PROFITS				
SECTOR	STEADY	NON COOPERAT.	COOPERATIVE	GAIN
HYDROPOWER.	8	7,66	10,87	3,24
IRRIGATION	52	53	65	14
JOINT	59	61	76	17

In summary, the results show that in the face of a scarcity of the resource, either as a result of meteorological phenomena or of larger water requirements, if the agents bargain a distribution of the water rights that is different from the initial situation, then such an agreement could achieve not only a mitigation of the losses caused by the scarcity (in the first case), but also an improvement in the joint profit of the system. This bargaining, according to the case in question, could be translated into permanent agreements that would suppose a change in the spatial and temporal distribution of the resource.

4. Conclusions

In this paper we have considered and proposed a resolution process for a conflict that is habitual in the allocation of water within a territory, namely competition between users for a resource that is regulated in different periods of time. To that end, we have developed a model that integrates the economic and institutional aspects with other equally important elements such as the temporal and spatial distribution of the resource.

So far as the methodology is concerned, the inclusion of these two latter variables supposes an improvement with respect to models that are characterised by considering only one period of time and that reflect the spatial aggregation of many users. As an additional added value, the form of constructing the model allows us to analyse different distributions of the use, which would be extensions or specific cases of the original scenario. In this regard a different temporal distribution will give rise to different constraints, but a similar logic would be followed in their construction.

All this notwithstanding, the central objective of this paper has been to characterise the possible cooperative agreements between users that guarantee better use of the resource. In this sense, the optimisation process that we have proposed sheds light on the direction that these possible agreements can take. The specific application carried out on the basis of real data for the Vadiello Reservoir (North East Spain) allows us to consider an example of how the allocation that maximises the objective function leads to a mitigation of the losses in dry periods, and to an increase in the joint profit when there is an extension to the surface area under irrigation.

These simulated situations have two aspects in common. First, the distribution of the resources over time is the origin of the conflict; secondly, the decentralised decision of the users represents a possible solution to that conflict.

This same scheme is applicable to situations that are, at first sight, different, but which, in their essence, only suppose changes to elements that we have considered as given. Thus, the evaluation in terms of profit of the construction of a new dam, the incorporation of a new user or the change of the minimum streamflow (for environmental reasons) are just three different examples of other possible applications of the model. In the first of these, the new dam will provide different distributions of the resource, whilst in the second and third there will be new time and space distributions for the flows.

In all these cases, it is necessary to consider the timing in the definition of the water right, together with both the quantity and the quality. This latter aspect (the quality) represents another of the logical extensions of the model. The main difficulty that such incorporation presents is that the water flows are not homogeneous, so that the intake and the return flows would not be capable of aggregation. Whilst the model does not consider these interesting aspects, we nevertheless believe that an approach of this type allows us to make progress in the necessary integration of the spatial and temporal characteristics of water within a scheme of an economic type.

REFERENCES

Bielsa, J (1999): *Gestión del Agua Integrada en el Territorio*. Consejo de Protección de la Naturaleza. DGA. Zaragoza.

Butcher, W.R and P.R. Wandschneider (1986): Competition Between Irrigation and Hydropower in the Pacific Northwest, en Frederick, K (ed). *Scarce Water and Institutional Change*. pp. 25-66. Resources for the Future. Washington D.C.

Colby, B.G; J. Crandall and D.B Bush (1993): Water Rights Transactions: Market Values and Price Dispersion. *Water Resources Research* 29, pp 1565-1572.

Dinar A. and A. Wolf (1994): International Markets for Water and the Potential for Regional Cooperation: Economic and Political Perspectives in the Western Middle East. *Economic Development and Cultural Change*. pp. 43-66.

Garrido, A (1994): Mercados de aguas: ¿entelequias economicistas o soluciones a los problemas de asignación?. *Revista de Estudios Agro-Sociales*. Nº 167, pp 89-112. MAPA.

Gibbons, D.C. (1986): *The Economic Value of Water*. Resources for the Future. John Hopkins University Press. Baltimore.

Griffin R.C and S.H Hsu (1993): The Potential for Water Market Efficiency when Instream Flows Have Value. *American Journal of Agricultural Economics* 75. pp 292-303.

Houston, J.E and N.K. Whittesey (1986): Modelling Agricultural Water Markets for Hydropower Production in the Pacific Northwest. *Western Journal of Agricultural Economics* 11. pp. 221-231.

MOPTMA. Ministerio de Obras Públicas, Transporte y Medio Ambiente (1993): *Estudio Coste-Beneficio del canal de Itoiz-Navarra*. MOPTMA. Madrid.

Sumpsi, JM; A. Garrido; M. Blanco; C. Varela; E. Iglesias (1998): *Economía y Política de la Gestión del Agua en la Agricultura*. pp. 63-93. Mundiprensa y Ministerio de Agricultura, Pesca y Alimentación.Madrid.

Winpenny, J.T (1994): *Managing Water as an Economic Resource*. Ed: Routledge, London.

Young, R.A and R.H Haveman (1985): Economics of Water Resources: A Survey. En Kneese and Sweeney (eds) *Handbook of Natural Resource an Energy Economics*, Elsevier, Amsterdam.