Received by Stout----3Feb2004

LW 04 006

Evaluation of Alternative Policies of Water Price for the Agricultural Use in Alentejo Region

Noéme, C.[*]

Fragoso, R.[**] *(P)*

Abstract

Irrigation is economically important in many regions of Mediterranean Europe such as the Portuguese region of Alentejo. The new Water Law proposed by the European Commission, pointing out that water management might be based on the principle of payment by users. These issues have some effect on the cost pattern of the farmers, when considering the water cost. However, the implementation of water tariff policies can provide a very important policy instrument, in order to promote an efficient use of water in agricultural sector as well as to avoid, at least partially, the loss of farm incomes. The main objective of this study is to evaluate the effects of alternative policies of water price for agriculture use in the farm income and the production pattern, having in account the recovery of the public investment and the operating costs with irrigation infrastructures. The methodology used is based, on the one hand, on the estimate of farm water demand and, on the other hand on the determination of the investment and on the current costs of the irrigation infrastructures. This study was applied to irrigated areas of Odivelas, in the South of Portugal.

Key Words: Price of Water; Irrigation; Alentejo; Mathematical Programming

1. Introduction

Throughout history, water has been considered an inexhaustible resource, and therefore free. The availability of water for agricultural, industrial and urban uses was guaranteed on the basis of social criteria. The Industrial Revolution of the 19th century, the population growth, the economic development and the urban concentration, brought about a growing need for water.

To satisfy the needs, there were made great public investments in infrastructures for the storage and distribution of water. This policy was very important for economic growth itself, as seen in the 20th century, but it was based on the increase of water offer, what leading to an indiscriminate increase in demand. In consequence, there was a rapid increase in the opportunity cost of the investments in water infrastructures, as also a degradation of the environment.

The increase of the opportunity cost in the new investments is related to the increasing scarcity of water resources, which gives rise to competition between the different alternative uses (Ohlsson, 1995). The intensive use of water with the objective of increasing agricultural productivity, intensify industrial growth and satisfy the needs of the urban concentration, has had adverse effects on the environment, such as the salination of soils and the excessive use of underground aquifers. The need to preserve the quality of the water and the growing value

[*] Instituto Superior de Agronomia, Universidade Técnica de Lisboa, Departamento de Economia e Sociologia Rural - Tapada da Ajuda, 1349-017 Lisboa Portugal, noeme@isa.utl.pt;

[**] Universidade de Évora, Departamento de Gestão de Empresas - Largo dos Colegiais 7800 Évora Portugal, rfragoso@uevora.pt;

of water in certain non-consumption uses, such as recreational, ecological and landscape enhancement, have gradually given rise to economic criteria in the management of water and in the allocation of water resources amongst different uses.

The increasing pressure on the demand for quality water and the compromises assumed in international agreements about the environmental policy lead the European Parliament to approve the Water Law (2000/60/EC) which establishes a new framework in the field of water policy.

The Water Law establishes that the costs of the water management services for the different uses should be necessarily defined by 2010 (Art. 9). For this purpose, an economic study should be made on the use of water in each Member State, taking into consideration the total water costs, including the environmental and scarcity costs. The methodology to be used should take into account the principle of the user - payer, and furthermore the definition of the measures that bring about the best cost / efficiency relationship for the different uses of water.

A resource has an economic value if its users are willing to pay a price for its use. According to Blanco (1999), the economic value of the water is not the only value. Prices vary in a sectorial, regional and individual level. In general, agriculture is the economic sector where most of the water is consumed and it is also the sector where the lowest price is practised. Just *et al*. (1997), maintain that the definition of some goals would contribute to obtain significant differences in the water price between sectors and areas. The low water price in the agricultural sector, would be related to the food sufficiency, to strengthen the competitiveness of the sector or to maintain the population in the rural regions.

The main difficulty in obtaining a water price consists in the evaluation of the environmental and scarcity costs. The water economy tends to be based on the neo-classical economic theory and on the theories of environmental management.

In the economic theory, costs will increase with production until incomes decrease. We can take the decision of production depending on the value of marginal costs and incomes. The interception of demand and supply will define the market price. However, the water can not be produced as a good, following the concept of economic theory. We have to find a specific methodology to find the water price.

The price of water in agricultural sector can be estimated from a demand function and from the total cost of the resource. The total cost may include the investment and operating costs of the irrigation structures and also the environmental constraint (Fragoso, 2001).

The economic analysis of the use of the water in the irrigated lands, has the objective of developing a prospective evaluation of the different options of economic, agricultural and environmental policies. These policies must be efficient and known by the producers. The known of the marginal cost of small amounts of water is very useful. It means the trade off among the alternative uses and generations (present and future).

The main objective of this study is to evaluate the effects of alternative policies of water price for agriculture use in the farm income and the production pattern, having in account the recovery of the public investment and the operating costs with irrigation structures. It was applied to Odivelas Irrigation Structure, in the South of Portugal.

This evaluation is done in terms of the consumption of water, of use made of the irrigated areas and of the agricultural returns, as also the recuperation of the costs with water. Two alternative water pricing policies were considered. One is based on the water demand derived at the farm level. The other is based on the average cost of water, which includes the investment and operational costs of the irrigation infrastructures per unit volume.

Besides the introduction, this paper includes three more sections: methodology, results of the model and conclusions.

2. The Methodology

The United States have been adopting tariff systems in the irrigated areas since some years ago. With the tariff systems, it has been possible to motivate producers into saving water and raising the efficiency of its use. The tariff system by landings, recommended by USA Bureau of Reclamation, has been analyzed by several authors (Wchelns (1991); Brill *et al* (1997); Michelsen *et al* (1998)). Brill *et al* (1997) compare different options to reduce the use of the water in the irrigated areas, namely the implementation of tariffs by landings, of tariffs according to the average cost, and the possibility of transferring water rights among users.

Michelsen *et al* (1998) have used an econometric model to analyse the farmers' mood for the adoption of tariffs systems of water to motivate its saving. According those authors, the tariff systems allowing promotion of the sustainable use of the water would be more easily adopted in the irrigated areas having high water cost or where the production options are based on crops with high value added. In the irrigated areas with high availability of water or with crops of low value added, the adoption of those tariff systems is much more difficult.

Montginoul *et al* (1996), have also analyzed the farmers' mood in some irrigated areas in France for adopting alternative models of service management. In their study, the authors were considered two management models: the introduction of quota, a tariff system or both. These systems of management of the water have been used in France. The preference between one or another system, depends mainly on the availability conditions of the water resources, as well as the demand characteristics. These authors conclude that the use of tariff systems varies strongly with the demand elasticity of the water price and with the share of the quantity tariff in the total payment for water. The demand for water seems to be sensitive to the price for some crops, as is the case of cereals, oleaginous and proteaginous, where the cost of the water represents an important part of their production costs. In the case of the crops with a higher value added, the water demand is rather sensitive to the price, being the water availability limitation the most important instrument to obtain a sustainable water saving.

Sumpsi *et al* (1996), evaluated the effects of volumetric tariff systems, landings systems and a mixture of both in the Spanish irrigated areas. Those authors concluded that the demand function of water was very inelastic. As a consequence, the use of the tariff systems in order to save water is only effective at high levels of water price, resulting in a loss to the farmers' incomes.

Concerning agricultural use it is not really granted that the rise in the price of the water gives an incentive for its saving. In fact, the consumption of water can even increase if the elasticity of the watering efficiency is more relevant than the price-demand elasticity (Huffaker *et al* (1995)).

According to the objectives of this study, the proposed methodology will analyse the behaviour of the water demand following different values for the watering price and, on the other hand, will analyse the cost of the water offer.

2.1. The Mathematical Programming Model

To represent the farmers' behaviour when confronted by different values of water price in irrigated areas, we developed a mathematical programming model adapted to the structural features of a farmer in the irrigated area of Odivelas, in the Alentejo. The discreet stochastic programming method suggested by Cocks (1968) and developed later by Rae (1971), is well adapted to the analysis of the agricultural production where the process of taking decisions is one of sequential type. Any decision about sowing, watering or harvesting, have to be taken considering that they depend upon each other and they are taken in a sequential way, being reviewed as time goes.

The model used is a sequential discreet stochastic programming one, based on the studies developed by Fragoso (1996; 2001), Jacquet *et al* (1997), Keplinger *et al* (1998) and Blanco (1999). This model maximise the expected farm income accounting the expectation of the occurrence of different conditions of the water use and the restrictions of the available resources (land, capital and labour). As the conditions of use of the water change (the water supplied), the producer can review his decisions changing the pattern of production, the production techniques, the amount of water to use and the amount of operating capital. The mathematical formulation of the model can be expressed as:

$$Max\ E(Z) = \sum_s p_s . Z_s \qquad (1)$$

$$s.a. \quad \sum_j \sum_a \sum_r \sum_t X_{j,a,r,t,s} \leq S \qquad (2)$$

$$\sum_j \sum_a \sum_{rm} \sum_t X_{j,a,rm,t,s} \leq SI \qquad (3)$$

$$\sum_j \sum_a \sum_r \sum_t q_{j,rm,t}\, X_{j,a,rm,t,s} \leq q_s\ , \quad being\ q_s \leq d_s \qquad (4)$$

$$\sum_j \sum_a \sum_r \sum_t NM_{j,r,t,ic,m}\, X_{j,a,r,t,s} \leq DM_{ic,m} + AM_{ic,m,s} \qquad (5)$$

$$\sum_j \sum_a \sum_t X_{j,a,r,t,s} \leq DEQ_{rm} + IEQ_{rm} \qquad (6)$$

where: $\boldsymbol{Z_s}$ is the annual farm income in the natural state of water availability s (€); $\boldsymbol{X_{j,a,r,t,s}}$ is the surface area of the crop j, according to the received subsidies a, the water regime or method of watering r and the production technology t, in the state s (ha); $\boldsymbol{q_s}$ is the total consumption of water in the natural state s (m3); $\boldsymbol{AM_{ic,m,s}}$ is the contracting of seasonal labour services and agricultural machinery ic, in the period m of the calendar and in the natural state s (h); $\boldsymbol{IEQ_{rm}}$ is the investment in irrigation equipment of type rm (ha); $\boldsymbol{p_s}$ is the probability of the occurrence of the natural state s; $\boldsymbol{S}$ is the total surface area of the farm (ha); $\boldsymbol{SI}$ is the surface area benefiting by watering in the farm (ha); $\boldsymbol{q_{j,rm,t,}}$ is the gross annual need for water for crops j (m3/ha); $\boldsymbol{d_s}$ is the gross average water availability in the natural state s (m3); $\boldsymbol{NM_{j,r,t,ic,m}}$ are the needs of the activity j in labour and agricultural machinery ic during the period m of the calendar (h/ha); $\boldsymbol{DM_{ic,m}}$ is the availability of labour and machinery ic during the period m of the calendar (h); $\boldsymbol{DEQ_{rm}}$ is the already installed capacity of irrigation equipment rm (ha);

The equation (1) represents the objective function which translates the maximisation of the expected farm income. The expected farm income results from the incomes obtained in each natural state (s) taking into account the respective probability of occurrence. The income is obtain from the difference between the revenue (sales and subsidies) and the production costs. The farm income can be interpreted as the gains obtained to the land and farmer's management.

The equations (2) and (3) represent the use of the total land and the use of the irrigated land, respectively.

The equation (4) concerns the conditions of the use of the water. On the right side we have the endowment of water supplied annually to the farmers in each natural state (s) and on the left side it is the total need of water for crops according to the watering system (unirrigated, pivot, cannon, sprinklers and drop-by-drop) to the production technique (more or less intensive). To represent the farmers' expectations in what is concerning the annual water endowment, we established three natural states (s): great availability of water, medium availability and small availability. These states were estimated through the distribution probability function of consumed water in the area of Odivelas along the years.

The equation (5) is concerned with the use of the labour and the agricultural machinery; the equation (6) represents the investment in equipment by watering type (pivot, cannon, sprinklers and drop-by-drop).

The model also includes equations respecting the financing of short term and other long term investments, the access of the producer to the banking credit and the restrictions imposed by the Common Agricultural Policy as regards to the setaside land.

The model allows simulation of the farmer's strategies following the application of water tariffs, namely in determining the effects on the consumption of water, on the farmer's income, on the pattern crops, as well as the recovery of the public investments. Considering the increase of the water costs, the farmer can adjust his activity through the:

a) change of crop areas;

b) change the use of the factors, reducing or increasing the operating capital;

c) substitution between irrigated crops and unirrigated ones;

d) change in the watering techniques;

e) improvement of the watering infrastructures in the farm.

2.2. The Average Cost of the Water

The Portuguese law classifies the public irrigated projects in four groups considering the social and economic impacts at national, regional, local and private level. In projects with national and regional impact, the Government has assumed its construction and the financing. The law foresee that the farmers would pay part of the total costs of that, which includes the investment and operating costs with the infrastructures.

The methodology used to calculate the average cost of the water follows the same philosophy of the Portuguese law to the public irrigated projects. In other words, for the average cost of the water, we considered the total costs of the initial investment, complementary benefiting infrastructures and the management costs, including the costs with the famers' watering office.

The average cost of the water don't include the opportunity costs and great part of the environmental costs. They aren't include by limitations of the methodology and by lack of available information. It is the case of no information about the costs originated by the contamination, as well as the erosion of the soils and on the biodiversity due to the watering water effects. The environmental costs considered are just those that are included in the maintenance services of the hydraulics infrastructures to guarantee the water quality and to avoid losses and wastes.

The calculation of the average cost of the water in the irrigated area of Odivelas in Alentejo, by the supply side, can be obtained by the following expression:

$$AC = [\ (\textstyle\sum_i IC_i \times CF_i) / VU + \sum_i (CC_i \times CF_{i,}) / \sum i\ ] / AB \times AVQ_n \qquad (7)$$

where: ***AC*** is the annual average water cost in €/m3; $\boldsymbol{IC_i}$, and $\boldsymbol{CC_i}$ are, respectively, the investment and operating costs in ***i*** year; $\boldsymbol{CF_i}$ is the capitalization factor (near tax rate); ***VU*** is the useful life of the infrastructures; ***AB*** is area (ha) of the benefited area; and ***AVQ*** is the annual average quantity of water demanded by the farmers.

3. The Results

In a first phase, we proceeded to the model validation, comparing the results obtained with the farmer's behaviour observed. The model results allowed to conclude that it represent in a general way the farmers' taken decisions and can be used as an instrument of prospective simulation. In a last phase, the model was used to estimate the water demand, considering the prices and the agricultural predictable subsidies in 2006, according to the main principles of the Common Agricultural Policy (Agenda 2000).

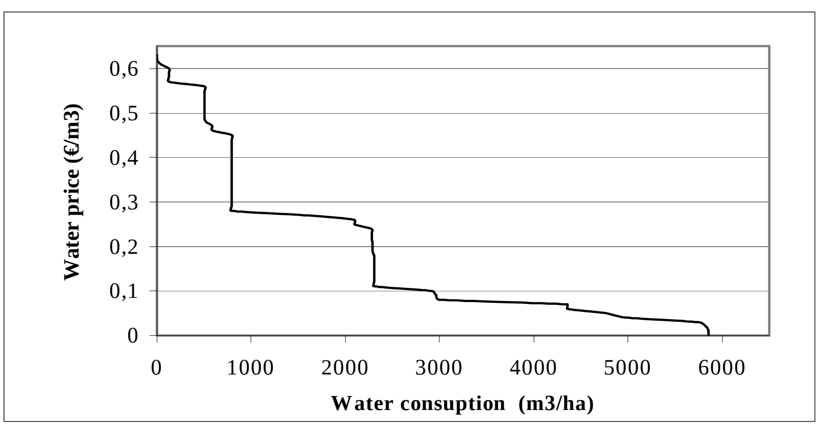
Besides the water demand, the results of the model allow us to know the effects of the water price in the production and in the farmer's income. On the supply side, the water price allow us to estimate how much would have the farmers to pay in order for the government and the society to recuperate the costs with the irrigated land infrastructures.

3.1. The Water Demand Evaluation

In Figure 1 the expected results of the water demand are presented. The demand of water is shown as the water consumed by hectare of potential irrigated area.

The consumption of water by hectare, when the water price is zero is about 5900 m3. That consumption does not change significantly for low water price (0,02 €/m3). Higher prices lead to a progressive decrease of the consumption, some stabilization being seen around 2300 and 795 m3/ha in the price gap between 0,11-0,24 €/m3 and 0,28-0,47 €/m3, respectively. Those gaps, such as the gap of 0-0,02 €/m3 correspond to the inelastic segments of the water demand function.

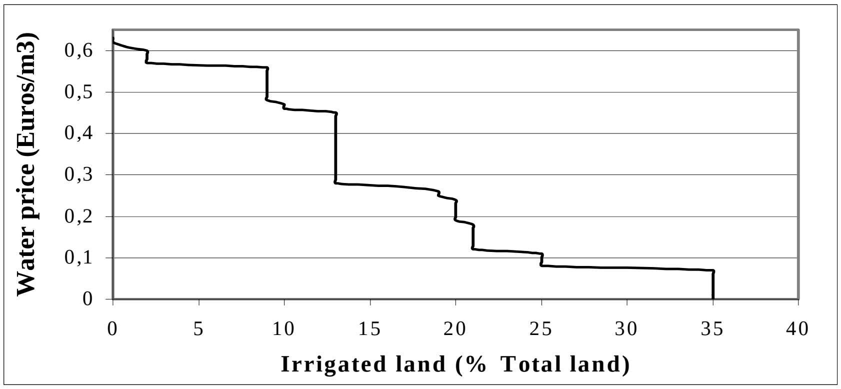
Figure 1. *Irrigation water demand curve*



Source: Model Results

Figures 2 and 3 present the effects of the water price policies in the irrigated area and in its use.

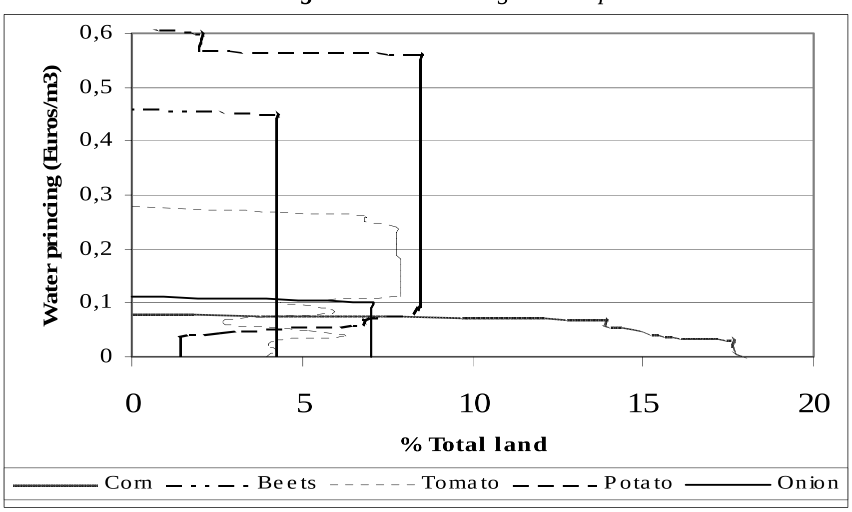
Figure 2. *Irrigated land*



Source: Model Results

Taking a water price up to 0,07 €/m3, all the irrigated area of the farm is cultivated, representing about 35% of total available agricultural land (495 hectares). When we consider 0,24 €/m3 for the water price, we can see that 20% of total area is irrigated land, representing 57% of potential irrigated area. However, if the price rises until 0,45 €/m3, the irrigated area will only represent 10% of total area and 29% of potential irrigated area. Considering a higher price up to 0,6 €/m3, the producer completely abandons the irrigated land.

Figure 3. *Pattern Irrigated Crops*

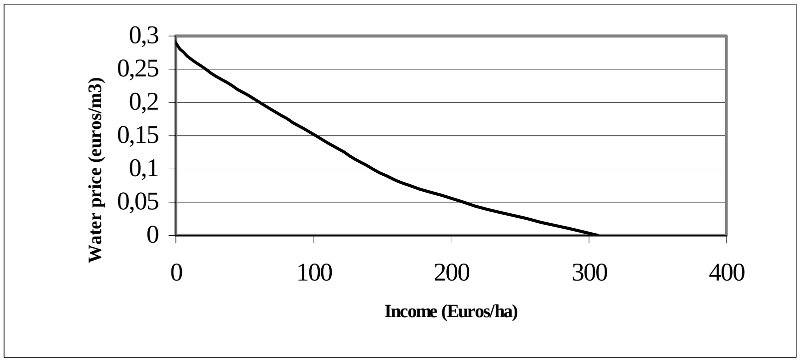


Source: Model Results

Considering the water price until 0,03 €/m3, the corn land represents 18% of the farm and 50% of the irrigated area, being the main irrigated crop up to a water price of 0,07 €/m3. The high profitability of the potato and the possibility of using sprinkler watering, allows it to constitute, in a certain way, an alternative to corn production for higher levels of water price (above 0,05 €/m3). Beet production represents only 4% of the total area and does not react to the increase of the water price, since its area remains the same until the water price is 0,27 €/m3. The onion reveals a profitable irrigated crop for water price lower than 0,1 €/m3.

When the water price is zero, the farm income is 300 €/ha and becomes negative when the water price is higher than 0,3 €/m3. Above this price level, the irrigated land is no longer profitable since it does not generate enough income to pay all factors, although it is possible to cover the operating costs until the water price reaches 0,6 €/m3 (Figure 4).

Figure 4. *Farm Income*

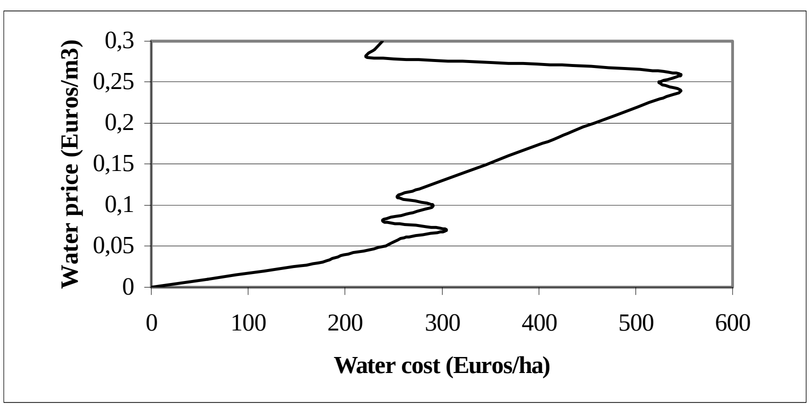


Source: Model Results

As expected, the greatest income losses occur when the water demand is inelastic, that is, in the price gaps 0-0,2 €/m3 and 0,11€-0.24 €/m3. In the first case, the income decreases from 300 to 265 €/ha and in the second one, from 134 to 29 €/ha, representing a loss of 12% and 78%, respectively. In the elastic sections of the water demand curve, the producers try to reduce the income losses, replacing crops more demanding of water by others less demanding or simply reducing the area of irrigation that is substituted by unirrigated or fallow ground crops.

In the Figure 5, the water costs by hectare of potential irrigated area are presented, corresponding, in fact, to the recovery of the public investment and the management costs of the irrigation infrastructures.

Figure 5. *Water Costs*



Source: Model Results

In the farm under study, the total costs with the water reach 300 €/m3 in a first phase, when the water price is 0,07 €/m3.

In the gap price of 0,08-0,13 €/m3 it happens a reduction of the total water cost, leading to a reduction of the watering area. From that price landing, the total water cost increases successively up to 545 €/ha, when the water price is 0,26 €/m3. From that price level on, the total water costs decrease successively and in abrupt way.

The greater increase of the total water cost is seen when the price gaps are 0-0,02 €/m3 and 0,11-0,24 €/m3. In those price gaps, where the water demand is inelastic, neither the water consumption nor the watering area decreases.

3.2. The Supply water price evaluation

The main infrastructures of the irrigated area of Odivelas are the dams of Odivelas and Alvito, as well as the primary and secondary watering networks of Odivelas.

The whole investment costs were estimated in 98,6 million euros, corresponding to an annual cost of 1,97 million euros. We have to add half a million euros for the operating costs. Considering the supply side, for the whole 6381 hectare of irrigated land, an annual average cost of 384,82 €/ha was calculated, which in the demand side corresponds to a price of 0,17 €/m3 (see Annex).

The calculated price of the water is in the second inelastic segment of the demand curve (0,11-0,24€/m3). At this price, the consumption of water will be 2300 m3/ha, representing to an irrigated area of 20% and about 50% of potential irrigated area. The production planning would be made up by potato, beet and onion. The farm income should decrease to 85 €/ha, that is, 70% from the income obtained when the water price is 0- 0,02 €/m3.

4. Conclusion

This study analysis the water price policies in an irrigated farm in the Alentejo Region of Portugal, according to the economic theory of demand and supply. The study of the demand was based on the prevision of the farmer's behaviour. For this purposed, a mathematical programming model adapted to the structural characteristics of the farm studied was developed, taking into account the main economical and institutional features. We used a discrete stochastic programming model that allows adjustment to a production planning according to the farmer's expectation, in that which concerns the water availability. On the supply side the water cost was estimated through its average cost.

The results allow us to conclude that the water demand is inelastic when the water prices are relatively reduced, up to 0,02 €/m3. At this price level there is no decrease either of the water consumption or of the watering area and crops replacement is not made. The corn is clearly the main irrigated land crop. The income is very sensitive to the raising in the water price. However, its reduction does not exceed 12%, when compared with a zero water price. When the price 0,02 €/m3 is exceeded, the demand becomes more elastic, and noticeable reductions in the consumption and in the watering area can be seen. Its effects on the income are partly softened by the strategy of the farmers to adapt themselves to less water demanding crops, such as the case of the potato and of the beet.

The average cost of the water was estimated in 384,82 €/m3, corresponding to a demand price of the water of 0,17 €/m3. At this level, the price at the supply side is placed in the inelastic demand segment and the effects would be strongly negative in what concerns the usage of irrigated area as well as the agricultural incomes.

REFERENCES

M. Blanco, (1999), *La Economía del Agua: Análisis de Políticas de Modernización y Mejora de Regadios en España*. Universidad Politécnica de Madrid, Tesis doctoral, Madrid.

E. Brill, E. Hochman, et D. Zilberman, (1997), *Allocation and Pricing at the Water District Level, American Journal of Agricultural Economics*, 79 (3), pp. 952-963.

K. Cocks, (1968), *Discrete stochastic programming, Management Science*, 15, pp. 72-79.

E. Daehnhardt, (1998), *Perímetros de Rega em Exploração: Algumas Características e Elementos Estatísticos até ao ano de 1996*. Direcção de Serviços de Hidráulica Agrícola, Instituto de Estruturas Agrárias e Desenvolvimento Rural, Ministério da Agricultura Pescas e Alimentação. Lisboa.

Directive 2000/60/EC, (2000), *Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 Establishing a Framework for Commmunity Action in the Field of Water Policy*. Official Journal of European Communities 22.12.2000, L 327 pp. 1-72.

R. Fragoso, (1996), *Évaluation des impacts socio-économiques du développement de l'irrigation: le cas de l'agriculture dans la région de l'Alentejo*. CIHEAM-IAMM, Collection de Thèses et Masters IAMM, n.º 40, Montpellier.

R. Fragoso, (2001), *Avaliação dos Impactos Sócio-Económicos de Plano de Rega de Alqueva no Sector Agrícola do Alentejo: o caso do bloco de rega da infra-estrutura 12,* Universidade de Évora, Dissertação de Doutoramento, Évora.

P. Hazell, et R. Norton, (1986) *Mathematical Programming for Economic Analysis in Agriculture*. Mac Millan Publishing Company, New York.

F. Jacquet, et J. Pluvinage, (1997), *Climatic Uncertainty and Farm Policy: A Discrete Stochasting Programming Model for Cereal-Livestock Farms in Algeria, Agricultural Systems*, 53, pp. 387-407.

R. Just, S. Netanyahu, et J. Horowitz, (1997), *The Political Economy of Domestic Water Allocation: The Cases of Israel and Jordan,* D.D. Parker et Y. Tsur (eds.), *Decentralization and coordination of water resource management*, pp. 89-114. Kluwer Academic Publishers, Boston, USA.

K. Keplinger, B. Mccarl, M. Chowdhury, et R. Lacewell, (1998), *Economic and Hydrologic Implications of Suspending Irrigation in Dry Years, Journal Agricultural and Resource Economics*, 23, pp. 191-205.

M. Michelsen, J. Mcguckin, R. Taylor, et R. Huffaker, (1998), *Irrigation District Adoption of Water Conserving Rate Structures, In: American Agricultural Economics Association, 1998 Annual Meeting «Responsible Resource Use in a Global Economy»*, Salt Lake City, Utah, USA, 2-5 August 1998.

M. Montginoul; et T. Rieu, (1996), *Instruments Économiques et Gestion de l'Eau d'Irrigation en France, La Houille Blanche*, 8, pp. 47-54.

A. Rae, (1971), *An empirical application and evaluation of discrete stochastic programming in farm management*. *American Journal of Agricultural Economics,* 53, pp. 625-638.

J. Sumpsi; A. Garrido; M. Blanco, C. Varela; E. Iglesias, et L. Avellá, (1996), *Estudio sobre a economía del agua y la competitividad de los regadíos españoles*. Secretaría General Técnica de Desarrollo Rural y Conservación de Naturaleza, MAPA, Madrid.

ANNEX

Average of water cost in Odivelas irrigation

Total equipped irrigation area (ha)	6381
Annual average available water (m3/ha)	8340
Annual average consumption (m3/ha)	2300
Useful life (years)	50
Investment costs (€)	98.554.500
Annual investment costs (€)	1.971.090
Operating costs (€)	484.500
Annual costs / ha of equipped irrigation area (€/ha)	384.82
Middle water cost (€/m3)	0.17

Source: Fonte: Daehnhart, 1999; and Watering Farmers Association;