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POLICY INSTRUMENTS FOR IRRIGATION WATER DEMAND MANAGEMENT: FLAT PRICING, VOLUMETRIC PRICING AND QUOTA REGULATIONS

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Abstract/Resumo:

In the fifty years since the foundation of the European Community, Europe has evolved in many fields. From being exclusively concerned with economic integration – reflected by policies to increase agricultural productivity and improvement of intra-communitarian trade –, nowadays, the European Union is gradually advancing towards a political integration, in the direction of common environmental values and towards the sustainability of natural resources. While in the Treaties of the European Community of Steel and Coal (1952) and Rome (1957) there is no direct reference to environmental issues, since the Treaty of Amsterdam this problematic issue has been a central theme of EU development, being clearly defined as one community objective to be reached. Frequently, in sustainability concepts only the degradation and misuse of natural resources are taken in account. This paper follows a different concept, where the discussion of sustainability is transferred to and placed in the context of a wider notion, integrating the political, social and economic dimensions of agricultural sustainability.

Having this framework in mind, this paper analyses the major implications that an environmental policy, such as the EU Water Framework Directive, may have when different policy measures are adopted. To accomplish this goal, the irrigated region of Baixo Alentejo, Portugal, was taken as a case study, using as a policy analysis tool a Multi-Objective programming model, based on the Multi-Attribute Utility Theory and on goal programming techniques, reproducing farmers' preferred behavior. The study focuses on the adoption and comparison of volumetric pricing and flat pricing policy measures, as well as on a consumption quota associated with the use of water resources.

Palavras-chave/Keyword: Water Framework Directive; Flat Pricing; Volumetric Pricing; Multi-Objective Programming; Goal Programming; Water Management

Classificação JEL/JEL Classification: Q28; Q12

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Abstract

In the fifty years since the foundation of the European Community, Europe has evolved in many fields. From being exclusively concerned with economic integration – reflected by policies to increase agricultural productivity and improvement of intra-communitarian trade –, nowadays, the European Union is gradually advancing towards a political integration, in the direction of common environmental values and towards the sustainability of natural resources. While in the Treaties of the European Community of Steel and Coal (1952) and Rome (1957) there is no direct reference to environmental issues, since the Treaty of Amsterdam this problematic issue has been a central theme of EU development, being clearly defined as one community objective to be reached. Frequently, in sustainability concepts only the degradation and misuse of natural resources are taken in account. This paper follows a different concept, where the discussion of sustainability is transferred to and placed in the context of a wider notion, integrating the political, social and economic dimensions of agricultural sustainability.

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1 - INTRODUCTION

Since ancient times the availability of water has been a central concern to all civilizations. In fact, it is recognised that the availability of water – besides allowing human survival – has an enormous social and economic importance, especially considering the vast implications it represents in the context of rural/regional development and for irrigated agriculture.

For many years, the constitution of water reserves and the construction of hydraulic infrastructures were considered as political priorities in several Mediterranean countries. This strategy was particularly notable from the mid 50, for instance, in the government of Salazar, in Portugal, and far more developed under Franco's regime, in Spain. Therefore, the political strategy of water management has focussed, almost exclusively, on the water supply side. As such, the unique concern was to promote available increases in the water resources; in this sense, it is generally agreed that water resources management has often been regarded under the perspective of "do nothing which might constrain" agricultural potential.

The current tendencies at the European Union (EU), have several explanations but, generally, are motivated and justified by society's increasing demand of water, by the appearance of environmental questions originated by agriculture – usually referred to as negative externalities – and by the recognition of the environmental importance of water resources (a non-use value). The concept inherent in the traditional term *sustainable agriculture*, as seen from the perspective of natural resources, tends to act, on the contrary, on the demand side; that is, implementing water demand management strategies, or regulating and controlling water supplies, stimulating increases in the efficiency of water use, which all serve to promote better uses of existing resources.[1]

The notion of *sustainable agriculture* that the authors wish to highlight, and that is the basis of this study, embraces a much wider concept, integrating multiple dimensions beyond the usual environmental approach. This notion recognises that nowadays sustainability concepts should also include a political dimension, with a strong presence at the EU level and clear in EU law under community Regulations and Directives; a clear social component, being this, that in the long run is intended to be sustained; and one economic dimension, interrelated with the previous ones, necessary to evaluate about the sustainability of agricultural systems.

From our perspective it is of fundamental importance to embrace a territorial/geographic vision, where the irrigated agriculture sub-sector is considered to be a contributing part of the promotion of sustainability and long lasting maintenance of agricultural activities. Irrigation can be considered as one possibility for integration and as part of the socio-economic regional dynamics, with an important role to play in subjects as diverse as the fixation of populations and creation of direct and indirect employment opportunities in impoverished areas, seldom characterised by human desertification. Nevertheless, one must not forget that agriculture is an economic activity that produces externalities and diverse multi-functionalities. Irrigated agriculture must be regarded from this perspective, among others, as a solid and strategic structure that supports and promotes regional development, socio-economic dynamics and the maintenance of viable rural communities, and both the noxious potential associated with productive activities and the constraining/enhancing effects over the environment and landscape need to be considered as well.

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[1] - The duality presented in these last two paragraphs illustrates the two fundamental strategies of water resources management, this is, water supply management and water demand management. The first one intends to enhance the resource availability, while the second one "addresses the incentives and mechanisms that promote water conservation and efficient use of water" (Cit. ROSEGRANT et al., 2000).

The aim of this study is to estimate the provisional impact that the Water Framework Directive (WFD) may have, by studying one irrigated area of Portugal (Baixo Alentejo) under different water policy instruments, evaluating three distinct levels of analysis, of the economic, social and environmental dimensions. Accordingly with the principles foreseen in the WFD, the implementation of water-pricing mechanisms, on a volumetric basis (price per cubic meter of water) and per irrigated surface (*flat pricing*, price per irrigated hectare) are simulated. On the other hand, given that the necessity of further integrating environmental aspects into Common Agricultural Policy (CAP) has implications at the water level, namely in the cross-compliance measures, the adoption of a water supply regulation (on a quota basis), constraining farm-level water use, is also simulated.

The analysis of policy effects followed in this study is performed by the use of a Multi-Objective mathematical programming model, combined with goal-programming techniques, in order to construct a multi-attribute utility function consistent with the actual preferences shown by Baixo Alentejo's farmers. By doing so, the methodology attempts to reproduce farmers' behaviour in respect to their productive patterns, considering the empirical objectives of maximizing farm incomes and minimizing risk, labour and operative capital.

The assessment of the impact of policy measures is achieved by following the evolution of economic, social and environmental indicators. In the economic analysis, indicators are designed to evaluate producers' income, CAP subsidies and water agencies' receipts associated with water-pricing. The social analysis intends essentially to estimate the agricultural labour requirements. The environmental component is performed by parameters included in mathematical models to evaluate the water consumption and intensity of input use, such as the use of nitrogen fertilisers.

2 – THE WATER FRAMEWORK DIRECTIVE (WFD)

In 1995, the European Commission and the European Parliament, in a joint effort, began the process of constructing a Common Policy concerning all aspects of water use. The WFD (Directive 2000/60/EC) was approved in the first half of 2000, during the Portuguese Presidency of the EU, under Article 147 of the EU Treaty[2], dedicated to the environmental protection (BOYMANNS, 2002), which forces all Member States to implement a water policy by the year 2010.

In fact, the EU, concerned with the *environmental sustainability* of water resources, developed the WDF in an attempt to avoid the future deterioration of water quality and with a view to the protection of water quantity as well.

Although environmental concerns in the heart of Europe are quite recent, they have become increasingly rooted since the mid 70. As far as the water problem is concerned one can already distinguish three evolutionary phases in its political integration. One can identify those laws belonging to the first phase as being intended to protect bodies of water for a particular use, such as the 78/659/EEC[3], 75/440/EEC[4], 79/923/EEC[5], 76/160/EEC[6] and 80/778/EEC[7] Directives. The second evolutionary phase is characterized by determining maximum emission limit values, where the 76/464/EEC[8] and daughter Directives, 91/271/EEC[9], 91/676/EEC[10] and 91/414/EEC[11] are good examples; the third phase, with a more integrated approach, is characterized by the appearance of the

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[2] - This article of the Treaty determines that the communitarian policy concerning the environment will be based on the precaution principles and polluter-payer principles. (EUROPEAN COMMISSION, 2000).
[3] - Fresh waters Directive to support fish live.
[4] - Drinking water Directive.
[5] - Shellfish water Directive.
[6] - Bathing water Directive.
[7] - Human consumption water Directive.
[8] - Dangerous substances Directive.
[9] - Urban waste water treatment Directive.
[10] - Nitrates Directive.
[11] - Plant protection products Directive.

96/61/EC[12] Directive (BOYMANNS, 2002).

As all these Directives are integrated in the WFD, it is a very wide-ranging document, with several and transversally diverse implications. To better explain this idea, it is important to mention that most environmental concerns and corresponding legislation produced since the mid 70s are present in this Directive. This is relevant, as it demonstrates that there is a qualitative concern with the state of water bodies, which is associated with a quantitative dimension.

Considering the environmental concerns at the water level, the Directive was established in order to implement a sustainable water management, preventing any further long-term deterioration, to protect water resources and preserving, or, whenever possible, improving the quality of the environment. Instead of insisting on water supply leading strategies, the WFD is based on the demand side, pursuing the most adaptable/local management, at the river basin scale.

The greatest paradigmatic change in this Directive is the reinforced introduction of economic instruments in environmental policies (EUROPEAN COMMISSION, 2000). In this case, water-pricing is the instrument chosen to accomplish all the desired objectives, that is, sustainable water use and the cost recovery of water services (in an economically efficient way) (EUROPEAN COMMISSION, 2000). It is foreseen that these goals are to be reached by the application of polluter-payer and user-payer economic principles (EUROPEAN COMMISSION, 2000) as integrating components of the full cost recovery principle (FCR).

FIGURE 1. Full cost recovery

FIGURE 2. Full cost recovery. Legend: EF – designates financial costs; O&M – Operation and maintenance costs; CO – opportunity costs, reflecting water scarcity and quality, these also include the valuation of environmental resource; the term Ext. designates environmental and economic externalities.

[12] - Integrated Pollution Prevention and Control Directive.

The FCR principle should consider all economic/financial costs (such as investment, devaluation, capital interests), as well as reflecting those costs affecting the environment and the resource itself (namely, scarcity and quality). The introduction of the FCR, as an application of the cited economic policy instruments, associated with water services (transport, exploitation, maintenance, management) should be understood from a broad perspective where all externalities (private, social and environmental) are also internalised.[13]

According to the OECD, 1999, the role reserved for water-pricing, as a primary way of achieving the correct conservation of this resource, is, in fact, the most controversial component of this Directive. Continuing to quote the same source, "the Directive's underlying philosophy is that the failure to make water users responsible for the complete costs generated by their use is a source of water misallocation – one which seriously jeopardises future generations' access to water"[14].

Actually, it is neither possible to determine with rigour the FCR component of resource opportunity costs, nor to fully quantify the amount of all externalities (positive and negative) associated with water use[15]. Therefore, their inclusion as FCR dimensions is only concerned with the political integration of the EU precaution principle with the use of economic instruments.

As far as the use of water pricing policies as demand regulation mechanisms is concerned, it should be stated that – from the consumers' point of view – the willingness to pay for water depends primarily on the production net added value originated by the last unit of water applied; that is, on the marginal productivity of water resources.

[13] - For a more detailed approach on externalities and opportunity costs, see HUFFAKER and WHITTLESEY, 2000.
[14] - The Price of Water: Trends in OECD Countries, OCDE, 1999.
[15] - The integration of agricultural externalities as FCR components, dichotomicly presupposes that all positive externalities from agricultural basis to be equally object of attention, dully quantified and internalised.

Accordingly to the United Nations (1993), the major dilemma of irrigation water-pricing consists in the accurate determination of the water price. If, on the one hand, a price stimulus is necessary to increase water use efficiency, on the other hand, it is essential to determine a ceiling-price, to prevent the abandonment of agricultural activities by a lack of ability to pay the cost of this factor. In fact, there is a wide scope of possible action in taxing water services, which may vary between FCR or revenue generation – that may inhibit irrigation – and the price associated with a zero marginal cost – thereby leading to the inefficient use of water resources (UNDP, 1993).

In any case, it is important to keep in mind that the inaccurate determination of water price (or prices) by government authorities may also produce a misleading advice about the utilization of social resources[16]. It is therefore necessary to implement an integrated water policy which combines farm-level policy effects with the wider society. This also needs to consider the allocative efficiency across sectors and regions at the level of the wide economy, instead of focussing exclusively on the irrigated agriculture sub sector (TIWARI and DINAR, 2001).

[16] - Adapted idea from Rosegger, 1975.

3 – CHARACTERIZATION OF THE STUDY AREA

3.1 – LOCATION AND GENERAL DATA

The Alentejo as a whole (see Figure 3) is one of the least developed regions of Portugal and of the EU, and the Baixo Alentejo is no exception. The Alentejo's contribution to the national product is quite low, approximately 4.6 %, and when calculated on a *per capita* basis represents one of the lowest values of the European Union. The sector of forestry, agriculture and fisheries still plays an important role in this region with a contribution of 15.1 % to the net added value of regional accounts.

As far as size is concerned, the Baixo Alentejo region represents nearly 13 % of the national area and about 16 % of the utilised agricultural area; on the other hand, only 1.3 % of the population resides in this territory (with 15.2 inhab./Km^2).

FIGURE 3. Location of the study area

3.2 – EDAFO-CLIMATIC CHARACTERIZATION

The entire mainland region of Portugal is characterised by a high degree of climatic and pedologic heterogeneity. In the analysis of these variables, it is possible to determine a clear break between the Northern and Southern parts of the country.

The Baixo Alentejo region, as far as pedology is concerned, is not different from the rest of the country. The centre and north of this region are occupied by Luvissols and Vertissols. In the south and northeast, the largest area is occupied by the group of Litossols, which continue their extension through the mountains of the Algarve (CARDOSO et al., 1973).

The average annual rainfall averages 586 mm, which is strongly concentrated in the winter season. The average temperature varies from a minimum of 9.6 ºC (in January) to a maximum of 24.0 ºC (in August). Far more important than these temperature and precipitation values are their distribution curves throughout the year (see Figure 4), where the phase displacement between extreme values of temperature and precipitation is notable in patterns of approximately six months.

FIGURE 4. Distribution pattern of monthly temperature and precipitation (average values).

4 – THE MULTI-OBJECTIVE METHODOLOGY IN AGRICULTURAL DECISION MODELLING

The fundamental problem of economics is the one of allocating scarce resources to alternative uses, making the most rational choices with the purpose of achieving certain objectives (MILTON FRIEDMAN, Cit. COCHRANE and ZELENY, 1973). Given the fact that resources are scarce, the problem is centred in the choice of some variable values, as a way of achieving those objectives and respecting all imposed constraints (INTRILIGATOR, 1971).

The use of simulation models based on mathematic programming is an instrument often mentioned in the literature focusing on irrigation and water problems. It allows the choice of optimum activities, or optimum combinations of activities, when modelling farms considered as being representative (BAZZANI et al., 2002). Generally, this problem can be designated as a constrained optimization (or maximization) problem, where constraints include crop rotations, potential limits to land use, water or labour, and market constraints or CAP constraints).

Mathematical programming models applied to agricultural enterprises often seek to optimise one single and well define objective. Most often, the objective function considers profit, gross margins or the optimisation of the value of sales. Unquestionably, this is an assumption which does not often exist on most farms. In reality, the decision maker – the farmer – seeks a compromise between several objectives, eventually in conflict (ROMERO and REHMAN, 1989). Regarding *ex-ante* analysis of agricultural or environmental policies, the authors believe that the traditional optimisation of one unique goal (for instance, income maximisation) does not fully reflect farmers' behaviour, and, consequently, does not lead to the best possible results.

The objective function considered is based on the Multi-Criteria Decision Making Theory (MCDMT), considering that the function to optimise is a utility function, composed of multiple attributes (Multi-Attribute Utility Theory) that the farmer wishes to optimize – maximizing his total utility. Therefore, it is a function composed of partial utilities, each one associated to each considered attribute (objective).

Using this methodology, the farmer's utility is not singularly conditioned by profit or gross margin maximisation; there are other objectives to which the decision maker reacts, such as risk, hired labour dependency, capital investments, fixed costs, leisure time or indebtedness (HAZELL and NORTON, 1986; ROMERO and REHMAN, 1989). Therefore, it can be seen that the farmer, when determining his crop-mix, may chose any combination of crops that contribute to the best achievement of his objectives.

4.1 – THE MULTI-OBJECTIVE MODEL

Having justified the choice of multi-criteria models[17], it is relevant to note that the utility function results from the summation of the contributions of all objectives. In this case were considered the land and entrepreneurial revenue (LER) maximization and, the risk (Risk), labour (TL) and operative capital (K) minimization. This is an additive utility function, where the model assumes that the total utility corresponds to the sum of

[17] - The words multi-objective, multi-attribute and multi-criteria are used indiscriminately in this document. Existing distinctions between terms and formulations are well documented, for instance, in MACCRIMMON (1973).

individual attribute's utilities. This fact implies that the various attributes are independent in their composite impact (COCHRANE and ZELENY, 1973). The general representation of a utility function with such additive and independent properties (KEENEY, 1973) may be represented by:

$$U_i(u_1+u_2+u_3+...+u_n)=f\left[f_1(u_1)+f_2(u_2)+f_3(u_3)+...+f_n(u_n)\right]$$ **[1]**

being f_i , $\mathrm{i}=1,2,...,\mathrm{n}$ exclusive functions of the attribute u_i.

It is important to mention that, under this methodology, the previous determination of f_i is achieved by the use of goal programming[18] techniques. As this study is guided by the attempt at reproducing farmers' behaviour, regarding their preferential objectives, the f_i values are calculated on the basis of previously revealed decisions, namely, those shown by their cropping choices. As the contribution of each objective have different measurement units, to allow the function additivity and enable it to translate into a meaningful value (GÓMEZ-LIMÓN and RIESGO, 2002), it must be rewritten with adimentional terms (normalising all objectives units). Therefore, this normalising process allows us to express the relative importance of each objective to the farmer's utility, and consequently to the decision making process. In this particular study, the knowledge of the coefficients (w's) attached to each objective allow to rewrite equation [1] specifying f_i and u_i as: **[2]**[19]

$$U=w_{LER}\frac{LER(\vec{X})-LER_*}{LER^*-LER_*}+w_{RISK}\frac{RISK_*-RISK(\vec{X})}{RISK_*-RISK^*}+w_{TL}\frac{TL_*-TL(\vec{X})}{TL_*-TL^*}+w_K\frac{K_*-K(\vec{X})}{K_*-K^*}$$

18 - This programming methodology considers all objectives simultaneously, minimizing the sum of deviations between optima objective values (targets) and expected ones (on the basis of farmers' choices). These deviations are then weighted accordingly to the relative importance that the farmer gives to the objective (ROMERO e REHMAN, 1989). Due to this fact, the adopted techniques belong to the particular group designation of "*weighted goal programming*".

19 - Adapted from GÓMEZ-LIMÓN, in press.

in which the symbols $[_*]$ and $[^*]$ indicate the anti-ideal and ideal values of the corresponding objective and $\vec{X}$ the productive activities vector.

4.2 – MODEL OBJECTIVES

As mentioned before, the objectives considered the same for all areas, are the land and entrepreneurial revenue (LER) maximization and the minimization of: risk (RISK), labour (TL) and operative capital (K). The mathematical formulation and some particular comments are separately presented for each objective.

- **Land and Entrepreneurial Revenue (LER) maximization** – It is relevant to make clear that this assessment of revenue cannot be perceived as neither a gross margin – as it takes in account devaluation costs – nor as a net margin, because land and entrepreneurial remunerations and private capital interests are not, in this case, deducted from the margin. Considering the dimension of study areas, within the *meso* analysis level, it is wise to admit the existence of a huge variety of farmers and this fact alone gives a good explanation for the use of LER as a preferred indicator in preference to others, as it allows the comparability of different activities when performed by farmers with very different characteristics (COELHO et al., 1998).

  Finally, it is also worthwhile to state that the use of this indicator as an income – as well as the gross or net margins – counter, functioning as a component of a multi-partial utility function, with additive properties and independency characteristics, does not influence the determination of farmers' goals, and, therefore, does not change the simulation process.

$$Max\ \mathrm{TLER} = \sum_{\mathrm{i}} \mathrm{LER}_{\mathrm{i}} X_i$$,

where (X_i) LER contributions of selected individual crops are added. **[3]**

- **Risk minimization (RISK)** – As a risk assessment indicator of the LER, the product of $\vec{X}'.[Cov].\vec{X}$ was calculated; where $[\mathrm{Cov}]$ represents the upper triangular variance-covariance matrix of the LER, for the selected crops in the considered period (three years), $\vec{\mathrm{X}}$ is the column vector of all possible activities (crops) and $\vec{X}'$ is its transposed row vector.
- **Total Labour minimization (TL)** – This objective aims at evaluating farmers' importance concerning minimizing agricultural labour. This indicator considers the labour used in general; that is, hired labour as well as family labour.

$$\mathrm{Min\,TL} = \sum_{\mathrm{i}} \mathrm{L_i X_i} \qquad \textbf{[4]}$$

where (L_i) is the unit crop labour requirements, and Xi is the activity dimension.

- **Operative Capital (K) minimization** – This intends to minimize the maximum amount of capital needed to carry out the farmer's productive plan (crop selection). The computation of operative capital is obtained by defining monthly crop sales and deducted them from crop costs. Therefore, K is not the mere summation of all costs across months; on the contrary, it is the maximum necessary capital to finance farming activities, on other words, it corresponds to the maximum level of indebtedness that the farmer is willing to face. On the following formula, the working capital in each month (WKN_m) corresponds to the product of individual crop needs for the different activities, ($WKM_{m,i}$) multiplied by the extent in which they are produced, added to previous months' capital requirements (WKN_{m-1}). It consists, basically, of a practical application of the "maxi-min" method to this situation.

$$\sum_i WKM_{m,i} * X_i + WKN_{m-1} < WKN_m$$
$$K > WKN_m \quad \textbf{[5]}$$

4.3 – MODEL CONSTRAINTS

The choice of constraints to include in the models is itself a peculiar task, because there is a trade-off between model prediction power and model reality adherence. If too many constraints are present, the model has a high adherence to reality, but, however, with very low predictive power. A less constrained model does not exhibit such fine adherence, but is further enhanced concerning predictive capacities – a fundamental characteristic to all policy change analysis.

Four main restrictions were imposed in the regional study models:

- **Land constraints.** The total area for crops and set-aside must be less then the availability of land. As mentioned, in each region, representative farms of 100 hectares were considered.

- **CAP constraints.**

  - Common Agricultural Policy set-aside measures were modelled. The compulsory set-aside surface was established at the 10 per cent value of COP crops (Cereals, Oilseeds and Protein crops); the voluntary set-aside was restricted to maximum of fifty per cent of the area declared to support purposes (COP + voluntary set-aside).

- Given the existing uncertainty over extending the production possibilities of activities subject to CAP quotas, all crops subject to these quotas were maintained constrained to their present values (the crops of durum wheat, sugar beet and industry tomatoes, for instance).

- **Market constraints.** Because of several commercial difficulties and the quick perishability of some vegetable crops, it was decided to impose a maximum ceiling on vegetable crop areas, correspondent to their present surface allocation.

- **Technical constraints.**

  - In the case of Baixo Alentejo, the single technical constraint, in fact restrictive, forces the area occupied by traditional Autumn/Winter crops (winter cereals) to be identical to that occupied by Spring/Summer crop ones (maize and sunflower).

  - To better simulate real conditions it was considered that, in cases where rice is produced, heaving in mind the necessary pedologic conditions and land preparation for irrigation purposes, this crop would have to have an upper limit.

It is also relevant to state that the analysis performed, which attempted to simulate farmers' conduct when facing policy change, and evaluating a wide set of variables, does not limit the values of those variables. For instances, water consumption or agricultural labour availability could have been constrained, but it is believed that this fact would inhibit the full understanding of the results evolution; on the other hand, it would introduce further constraints with all the implications above mentioned.

4.4 – MODEL APPLICATION TO THE STUDY AREA

The multi-objective formulation technique is used to identify the main objectives that are considered during the decision making process and to what extent they intervene. Once the model already described has been built and once all reasonable objectives are optimized, a *pay-off* matrix is obtained – (m*n matrix, with m=n) – gathering the necessary information to compare observed decision variable values, with those generated by optimising model individual objectives (see table 1).

Pay-off (or trade-off) matrices summarise several information. For instance, on the main diagonal of this matrix, in dark blue, are shown the individual objectives' optimum values; the remaining cells illustrate the corresponding objective value (in rows) when another objective is being optimised (in columns). Notice that the last column does not really belong to the matrix. Nevertheless, the inclusion of this new column allows the direct comparison between simulated conflicting goals and present reality values. This comparison very strongly suggests that the best simulation of farmers' behavioural preferences is attained via a combination of multiple objectives, instead of modelling one unique one.

TABLE 1. Baixo Alentejo *pay-off* matrix (100 ha farm)

4.5 – THE UTILITY FUNCTION

TABLE 2. Objectives Coefficients

After determining the pay-off matrices and farmers' preferences concerning the coefficients attached to each objective (see left-hand values), the next step consists in constructing the utility function that integrates these objectives in the appropriate degree of relevance (see **[2]).**

B. Alentejo **Utility = 1.31*TLER - 4.88E-5*Risk**

4.6 – Model Validation

Similarly to the traditional approach of profit maximization – which assumes that the objective is obtained at highest profit –, the Multi-Attribute Utility Theory assumes that the farmer produces at a location that assures the maximum utility. The model is validated by comparing the combination of activities which maximizes the utility function (reflecting producers' preferences), and the observed crop actually made by farmers. This step enables us to determine if existing deviations (between activity areas) are small enough to consider the model representative of reality (adherent) or, on the contrary, if the model does not reproduces farmers' behaviour.

Table 3. Baixo Alentejo model validation

From the analysis of Table 2, one must conclude that the model reproduces farmers' crop selection with high accuracy. Therefore, the model is considered to be adherent to reality.

5 – Results

It should be highlighted that this study only intends to analyse some of the multiple implications inherent in the adoption of water management policies. This section compares, on the one hand, the adoption of a volumetric pricing policy and a flat pricing tariff (per irrigated hectare); on the other hand, it sketches a first approach to introducing water environmental concerns into CAP policies, namely, at the cross-compliance measures level. To do so, whenever possible, the implications of adopting each policy scenario on the water consumption are compared, by evaluating the water demand curves under each situation; the crop-mix change; the social change, as a response to labour allocation to this activity sector; and at the farm level income transfers, to agriculture – via direct subsidies – and from agriculture, to a water agency – as a direct result of water pricing

All figures and data presented refer, except indicated opposite, to hectare units.

5.1 – WATER DEMAND CURVES

The evaluation of water consumption is a central aspect of this analysis. This indicator is vital in attempting to foresee any implication of CAP or WFD on environmental conditions, especially on water. The water demand is calculated via the parameterisation of its price(s) or quota levels; as a result, it is possible to know the amount of water demanded at a particular water price, or to determine a shadow price, in the case of water quota simulation.

As is known, the demand curve corresponds to the illustration of the demanded quantities of a given good, to greatly different price levels (maintaining all other factors constant). The water demand, as any other production factor, is a derived demand. In the particular case of water, the demand curve reflects (in Mediterranean conditions) the crop vital biological necessity for a transporting vehicle of other production factors, and it also reflects the valorisation acquired through the direct transformation of water inputs into agricultural outputs.

Figure 5 exhibits a negative price-quantity relationship, as would be expected for all policy instruments. This fact indicates that water pricing and water quota regulating vary in an opposite direction to water consumption. Both situations that imply an associated price were obtained by parametrising the pricing form (per cubic meter and irrigated hectare). The water demand curve associated with the quota regulation measures the willingness to pay, being determined by the shadow price of water resources and it also measures the marginal utility that one unit of water is able to generate.

In these curves it is notable that the greatest efficiency of policy instruments are achieved under the volumetric pricing and quota regulation situations.

The flat pricing situation curve is characterized by extensive inelastic segments, without any response to price increases. The justification of this occurrence lies in the fact that indirect policy instruments, such as those based on surface units – like flat tariffs – are independent of the water volume consumed and, therefore, do not lead to more efficient uses (TSUR and DINAR, 1995) or more efficient crops. This is due to the fact of not changing the marginal productivity relation at the farm level, maintaining unchanged the user marginal cost. Moreover, when water consumption increases, the marginal costs tend to decrease; particularly in those situations where water is delivered upon request and water quantities do, in fact, increase significantly, these systems do not promote the best resources use nor are conducive to efficiency increases (TSUR and DINAR, 1995; EUROPEAN COMMISSION, 2000). Indirect pricing schemes may inclusively serve as incentives to the use of larger quantities of water (TIWARI and DINAR, 2001).

FIGURE 5. Water demand curves

In the present situation, where the price charged per cubic meter is near zero and without the presence of quotas, the average consumption per irrigated hectare is 2999 m^3. For a situation corresponding to a water price of 0.1€/m^3 the water consumption (average amount per hectare) decreases to values of about 2566 cubic meters, in the scenario of volumetric pricing, and to, approximately, 2570 m^3/ha in the quota regulation situation; this represents a 14% reduction in water consumption. Under these situations, a 0.1€/m^3 price increase implies more than 10 per cent water consumption reduction. Regarding flat tariff payments, at this same level of water price, there is no indication of any change in the water volume consumption.

5.2 – Crop Mix Change

As several authors have pointed out[20], water price increases (on a volumetric basis) induce, in the short-term, a decrease of water consumption for the installed crops and, in the medium/long-term induce crop-mix and technological changes. Here, we will only focus on the aspect of crop-mix change.

In the following figures it is possible to note that all irrigated crops respond to water pricing and quota regulations with the diminishment of their areas. The evolution of irrigated areas in different scenarios advances in almost absolute concordance with their respective water demand curves.

Figure 6. Irrigated area evolution

It is precisely those crops which consume most water (rice, maize and sugar beet), or with very reduced profitability, which are the most affected in situations of water demand constraining and volumetric pricing. Volumetric tariffs presuppose a direct utility reduction, and given the fact that the relative profitability of different crops varies with water price, crops which consume less water or are rain-fed progressively become more profitable alternatives. As situations of regulating water demand through abstraction quotas

20 - See, for instances, the work of Zilberman and Lipper (1999) and Tsur and Dinar (1995).

do not presuppose a payment, they evolve by the necessity of better remunerating a gradually more scarce production factor. Therefore, just as in the previous situation, crops which consume more water are put aside.

The hectare payment scenario is completely different, and as it is an indirect method, there is no direct relation between quantities of water demanded and pricing. This method implies that all irrigated crops are equally influenced, in absolute values, in their profitability reduction. Therefore, it happens that the crops with the lowest profitability levels are removed from production, instead of those more water consumptive.

One other interesting aspect to note – that satisfies farmers' behavioural attitudes – is the dramatic increase of the area allocated to set aside (compulsory and voluntary). In this analysis, the quota policy, in comparison to water pricing, is revealed to be the most effective instrument for maintaining irrigated agricultural activities in active production, while simultaneously attaining some environmental achievements.

FIGURE 7. Set aside evolution

5.3 – SOCIAL IMPLICATIONS

Resembling previous situations, figure 8 reveals that the analysed policy instruments lead to the reduction of direct agricultural employment. If the simulated crop-technology relation is kept constant, the crop-mix change described runs in parallel with a reduction in demand for agricultural labour.

FIGURE 8. Labour demand curves.

The lack of responsive capacities characteristic of the flat-pricing method (in comparison with the other two), is in this particular field an advantage in maintaining rural populations allocated to agricultural activities.

5.4 – Economic implications

5.4.1 – Agricultural Income

As would be expected, farmers' income varies in the opposite direction to water pricing or water constrained consumption. Figures 9 and 10 illustrate that water consumption reductions correspond to points of lower income. Concerning water consumption reductions, via price effect, they are responsible at first for quite significant income decreases, while the following ones have a lower repercussion, and only contribute to the tendency of reinforcing the abandonment of irrigated crops – with the consequent income lowering to levels close to rain fed extensive farming.

Figure 9. Income evolution – water consumption

Figure 10. Income evolution – water price

Farmers' income reduction via price increase has two main fundamental causes. On the one hand, water-pricing presupposes increased costs. On the other hand, as the water price is increased, there is a notable crop reallocation; that is, the price effect is unequally reflected – in absolute values – in the different preferred crop choices and, therefore, the relative profitability leads to a new crop-mix. As already mentioned, with the volumetric pricing, it is precisely the crops which demand the most water which generate the most significant contributions to farm economic results, which are progressively pushed back from the productive plan. In the quota instrument only this second component is decisive;

and it happens by model-internal resource valuation (model endogenous) in the face of increasing resource scarcity.

5.4.2 – INCOME TRANSFERENCES

It is important to highlight at least two income transfers: the capacity of policy instruments to generate revenues to face the costs of water services (farmer transfers to water agencies); and the assessment of direct payment transfers promoted by newly chosen productive plans (government transfers to farmers).

FIGURE 11 - 12. Income transfers

Regarding the first perspective – assessing transfers to water regulating agencies (government, private associations or combined systems ownerships) – it is possible to note in figure 11 that the maximum receipt associated with an irrigated surface payment corresponds to a situation that does not promote crop-mix change and, consequently, has no impact on water consumption. This maximum receipt is approximately the 300 Euro per hectare, reached with an income sacrifice of 33.6 %. The maximum value associated with a volumetric pricing system is slightly superior to 350 €/ha, correspondent to an agricultural income sacrifice of 48.5 %, with a water price of 0.16 €/m^3 and to a water demand reduction of 26.3 %. Water regulations such as quotas imply an extra implementation cost, impossible to quantify with a farm level analysis.

Concerning income transfers associated with support given to farmers through direct payments, both volumetric pricing and water demand quotas – those instruments that better allow a productive reallocation – go almost together. In the irrigated surface scenario, the amount of granted support is maintained as long as there is no incentive to remove from production the crops which are the object of those subsidies.

6 – Final Comments

If we assume that concerns surrounding the concept of sustainability will acquire increasing importance at the heart of the EU and in modern society, this concept must be better defined. Priorities and preferential objectives to what is intended to be sustained must the made. To each particular objective, there is one unique policy instrument that best serves that purpose. When policies are adopted to respond to diffuse and unclear objectives, they are doomed to failure for most of those objectives.

It is relevant to mention that if the objective is the protection of bodies of water against excessive use, a regulation instrument such a quota policy will be perfectly suited; if the priority is to promote a rational and efficient water use, the best policies to implement would be a tradable rights policy (in the water markets direction) or volumetric pricing policies, at constant or variable (multi-rate) pricing levels; if the objective is to reflect the full cost of water services or to generate revenues, then the instrument must clearly be economic, such as the adoption of volumetric pricing methods.

In the situation of Portuguese irrigated agriculture, in this study case contextualised in the region of Baixo Alentejo, it is very necessary to state that whatever the objectives may be, it is fundamental to have them accompanied by technical support measures, to create, develop, and reinforce the technological adoption possibilities that may target water use efficiency and minimise negative environmental impacts.

Irrigation is expanding in Alentejo region due to Alqueva dam (it is anticipated that 110000 hectares will be irrigated by 2025), so it is very important to very quickly make the objectives in order to avoid any wrong decisions that could have negative effects in the medium and long terms.

Considering all that has been said, it is very necessary to find a compromise solution, from the political point of view, that equates all these dimensions in the best interest of the future of agriculture, of the reinforcement of its competitiveness, without ceasing to consider the possible implication for human desertification, rural development, in this regional/local context where agriculture is often the unique economic activity propelling development.

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8 – TABLES

TABLE 1. Baixo Alentejo *pay-off* matrix (100 ha farm)

Baixo Alentejo	Objective to be Optimised				Observed Value
	TLER	Risk	TL	K	
TLER (€)	**95656**	30960	53058	53293	72324
Risk (€^{2})	22234735	**632876**	4316451	4601512	21998460
TL (h)	6284	7484	**1239**	1333	14963
K (€)	78032	59854	25071	**24708**	95995

TABLE 2. Objectives Coefficients

	B. Alentejo
WMAXLER	0.989
WMINRisk	0.011
WMINTL	-
WMINK	-

TABLE 3. Baixo Alentejo model validation

Activities	Observed Value (ha)	Multi-Objective Model		
		Obtained Value (ha)	Deviation (%)	Deviation (ABS acum.)
Wheat	21,7	26,2	-4,5	4,5
Durum Wheat	10,9	10,9	0,0	4,5
Maize	16,8	18,6	-1,8	6,3
Rice	3,4	3,4	0,0	6,3
Sugar Beet	3,9	3,9	0,0	6,3
Sunflower	17,0	18,6	-1,6	7,8
Ind. Tomatoes	5,8	5,8	0,0	7,8
Vegetables	5,2	5,2	0,0	7,9
Olive Groves	8,6	-	8,6	16,5
Set-aside	6,6	7,4	-0,8	17,3
Total	100,0	100,0	-	**17,3**

9 – FIGURES

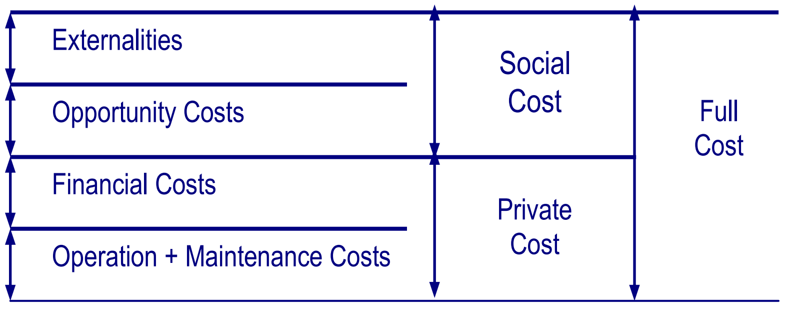


FIGURE 1. Full cost recovery

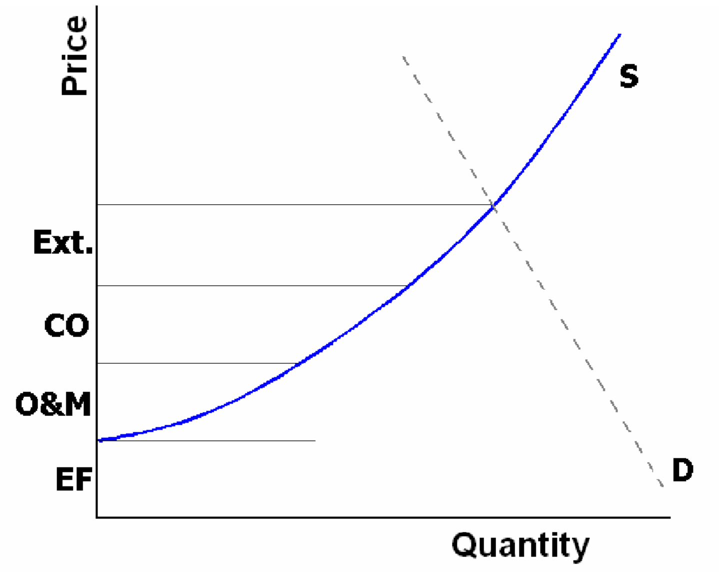


FIGURE 2. Full cost recovery. Legend: EF – financial costs; O&M – Operation and maintenance costs; CO – opportunity costs, reflecting water scarcity and quality, these also include the environmental resource valorisation; the term Ext. designates environmental and economic externalities.

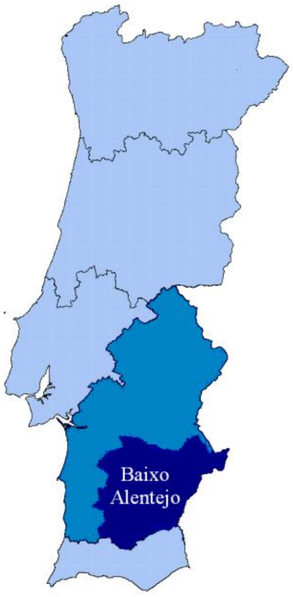


FIGURE 3. Location of the study area

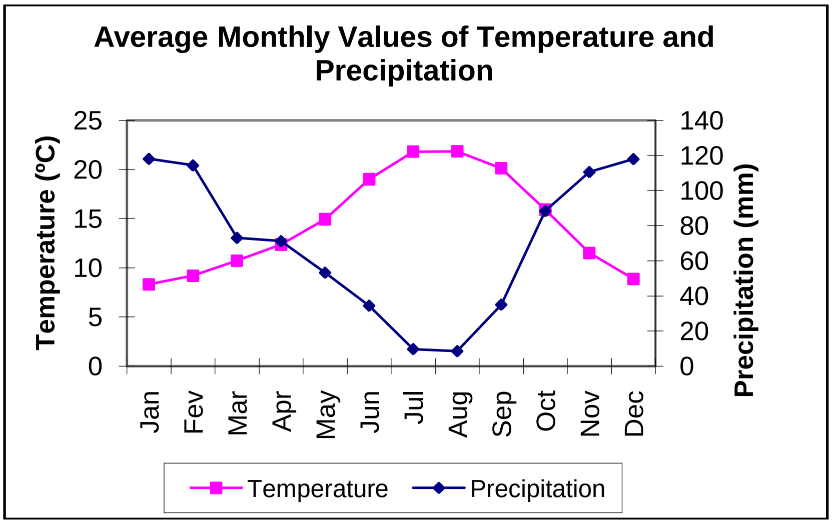


FIGURE 4. Distribution pattern of monthly temperature and precipitation (average values).

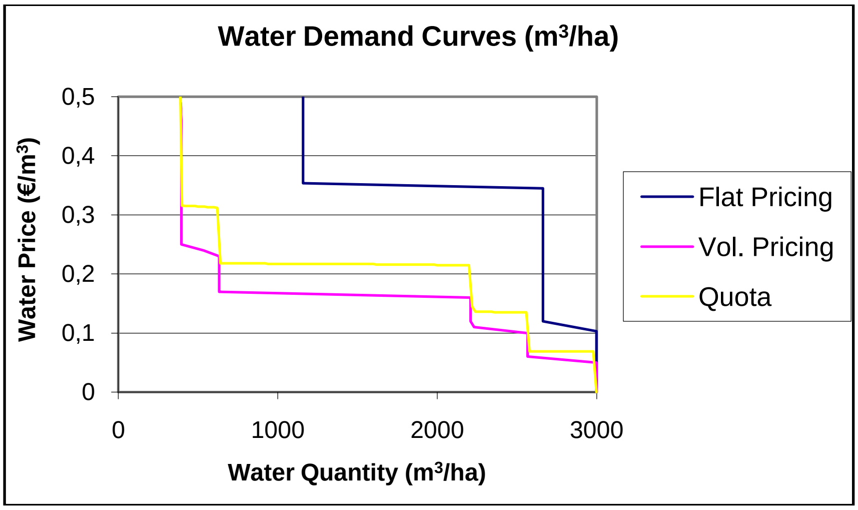


FIGURE 5. Water demand curves

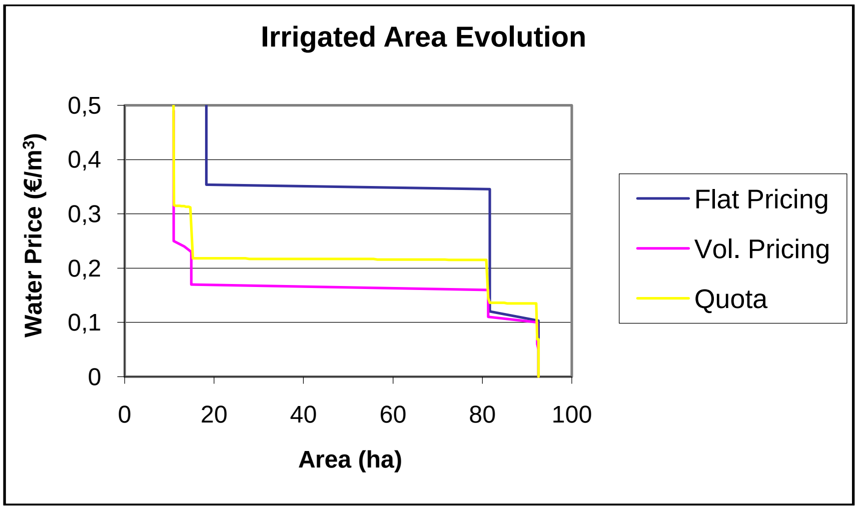


FIGURE 6. Irrigated area evolution

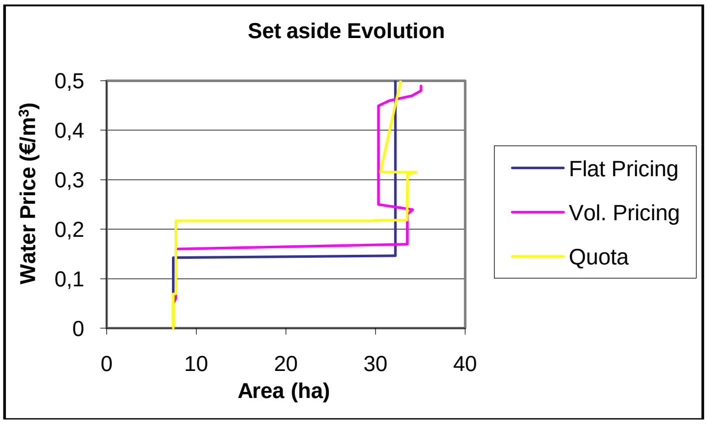


FIGURE 7. Set aside evolution

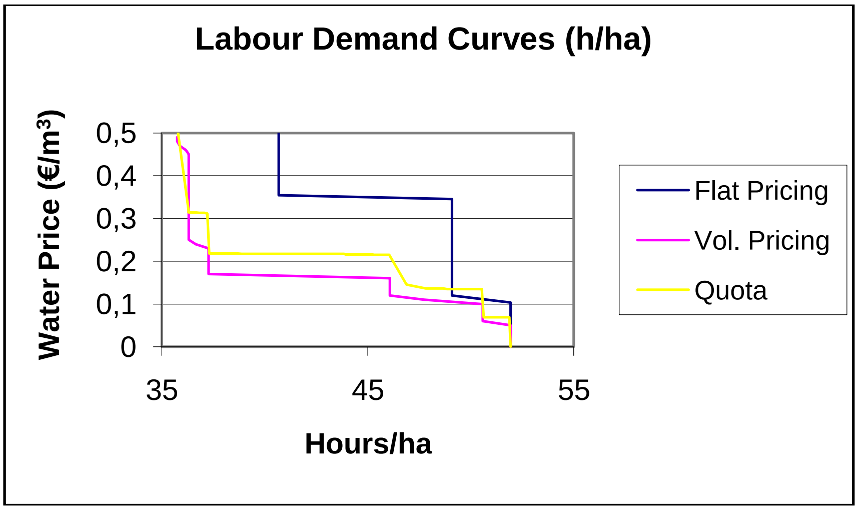


FIGURE 8. Labour demand curves.

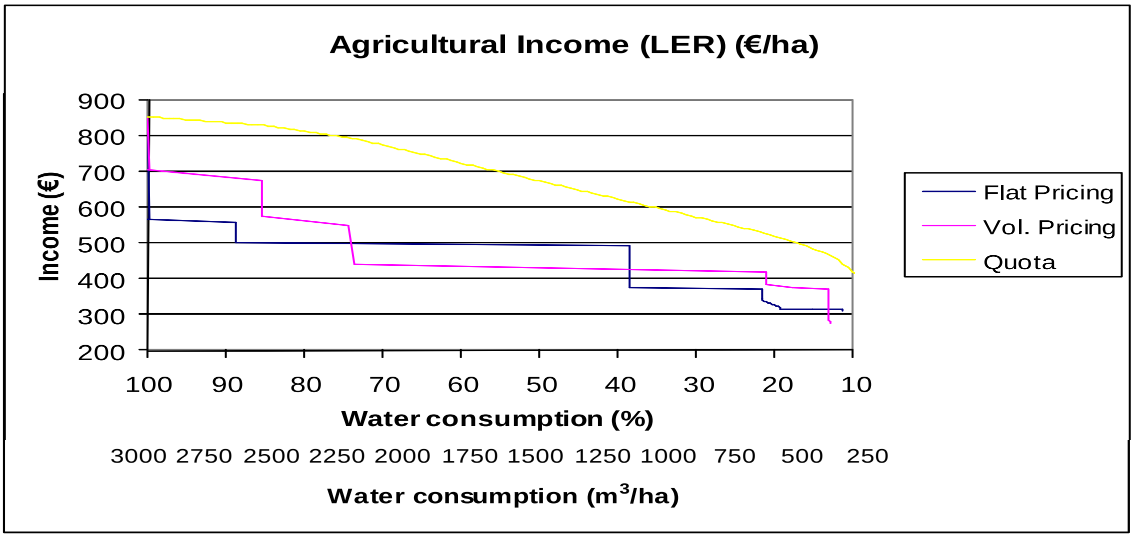


FIGURE 9. Income evolution – water consumption

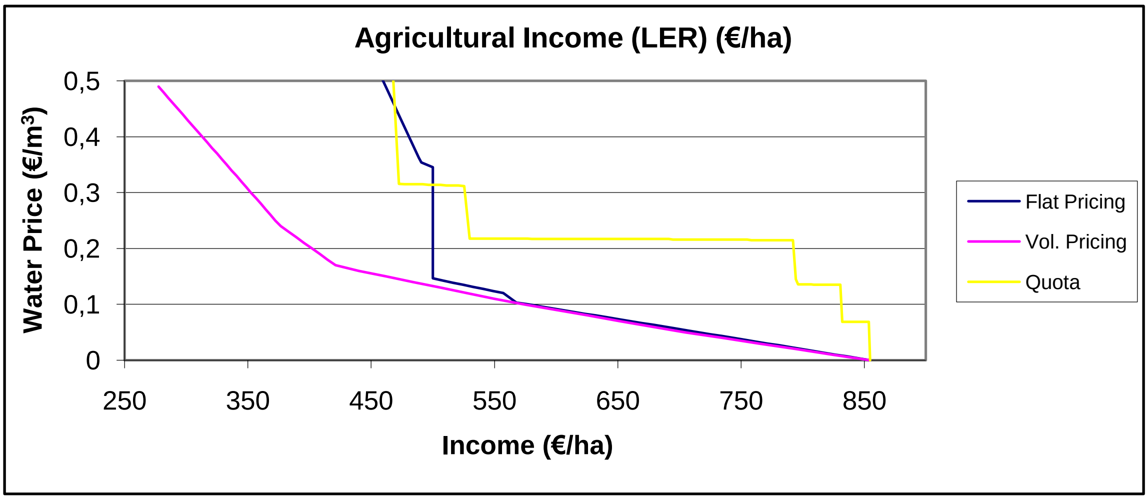
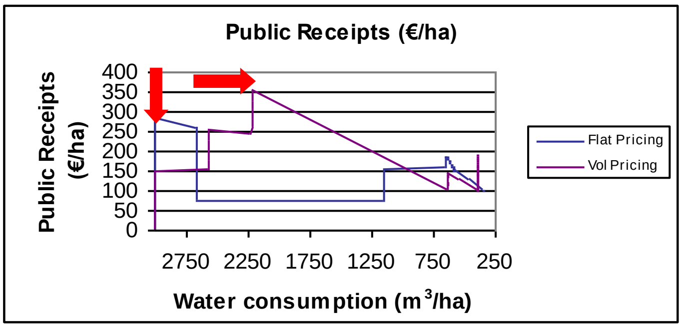


FIGURE 10. Income evolution – water price



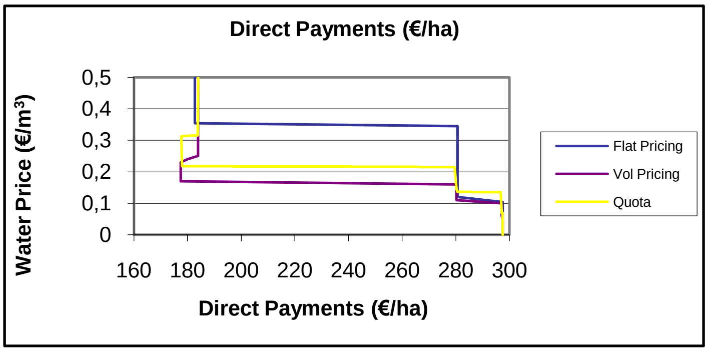


FIGURE 11 - 12. Income transfers