This book summarises the European research project WADI, which has focused on how agricultural economics and decision theory can be applied to European irrigated agriculture, which is currently at a normative crossroads. The WADI project has involved ten institutions which have utilised a common methodology to study the sustainability of irrigated agriculture in Europe in the context of post-Agenda 2000 CAP Reform and the Framework Directive on Water. The consortium has also applied this common methodology, which is based on multicriteria analysis of farming systems, to a wide range of irrigated systems all over Europe. Another important methodological innovation of WADI is the integration of sustainability indicators for analysis of the impact of alternative policy scenarios in farming systems. The results show that the evolution of crop mixtures over time is highly dependent on the political environment that results from the Common Agricultural Policy and the application of the Water Framework Directive. A further conclusion is that there are important differences between the irrigated systems of individual European countries. This suggests that there is a need for an in-depth analysis of local conditions and the impact of the European normative framework.

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Sustainability of European Irrigated Agriculture under Water Framework Directive and Agenda 2000

SUSTAINABLE DEVELOPMENT, GLOBAL CHANGE AND ECOSYSTEMS

EUROPEAN COMMISSION

Sustainability of European Irrigated Agriculture under Water Framework Directive and Agenda 2000

WADI

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Directorate-General for Research
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Part II

1.

FOREWORD

The Water Framework Directive (WFD) is probably the most ambitious European effort for a common integrated management of environmental resources in the Union. The WFD states that Water is not a commercial product like any other rather it is an heritage which must be protected. Irrigated agriculture is the largest consumer of water in European Mediterranean areas, and an important economic activity in the rest of the European landscape. On the other hand, the Common Agricultural Policy (CAP) influences decisively the use of water in irrigated systems, thus the need for research on the optimal integration of both policies conducted by the WADI[1] consortium.

This book aims to present to the European society the results of the WADI project, trying to provide a European wide summary of potential consequences of the WFD application in irrigated systems as well as detailed country results. Finally, some additional chapters are included presenting a review of methodology, applied scenarios, the water framework directive implementation and the original research objectives.

All research institutions involved in the WADI Project want to express acknowledgement to the European Commission for the financial support it offered to our project through the V Framework Programme for RTD (1998-2002). Also we have been supported by DG-ENV and JRC-IPTS staff which contributed to the improvement of the technical quality of our work. Nevertheless the WADI consortium is responsible for the final result and the opinions contained in this publication.

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[1] The WADI consortium was financed through the 5th Framework Programme for RTD under the contract **[EVK1-2000-00057]** and with the title:'**Sustainability of European irrigated agriculture under water framework directive and Agenda 2000**'. The Universidad de Córdoba was the coordinator and the partners were: Univ. Valladolid (E); Federación Nacional de Comunidades de Regantes (E); Univ. Evora (Pt); Centro Studi Aziendale (I); Univ. Bologna (I); Univ. Thesaloniki (Gr); Univ. Cranfied (UK); Joint Research Centre (COM-EU).

We are very grateful to many colleagues who supported our research by supplying us with valuable information. Thanks are due to Andrea D'Amore, who is not in the credits but who was part of the initial design and left us for other projects. Probably we will not be here without his personal support and human quality.

The project general objective was to *analyse the sustainability of irrigated agriculture in Europe in the context of post Agenda 2000 CAP Reform and of the Framework Directive on Water.* In order to achieve this objective, the following modules were carried out during the period Feb. 2001 to Feb. 2004:

(A) Qualitative analysis scenarios building and selection of indicators
(B) Quantitative analysis: Models of farming
(C) Integration: From models of farming to regional scenarios
(D) Diffusion

The consortium has done an interesting job and we have attained most of the goals proposed originally, testing the methodology and applying it to various farming systems all over Europe. Readers will see in this final report document the impact of various water price and CAP & WFD scenarios on the sustainability of irrigated agriculture. For a complete analysis of the WADI reports and deliverables please visit the following address:

www.uco.es/grupos/wadi

The present publication has been structured on the basis of the final report of the WADI project and it is divided into three parts:

I- Summary, general conclusions, applied scenarios and methodology
II- Case studies
III- Epilogue: agricultural economics in the implementation of the WFD.

This work is the result of a multidisciplinary and collaborative research approach, and even though some chapters are signed by their principal researchers or final publishers, we can affirm that all the members of the WADI consortium have contributed to improve the work of each partner. The methodology employed is the final result of a process of consensus building in which all partners have contributed to a common framework that was subsequently implemented in each case study.

2.

OVERVIEW

Berbel, J.[1]; Gomez-Limon, JA.[2] y Viaggi, D.[3]
[1] University of Cordova, Department of Agricultural Economics
[2] University of Valladolid, Department of Agricultural Economics
[3] University of Bologna, Department of Agricultural Economics

1. Background

Economics is the science that deals with limited resources that are capable of being used to satisfy human needs, and classical economics stressed the power of the market both to stimulate growth and serve the interests of society as a whole. In the 1950s, government intervention was justified when markets failed, and most policy models were based upon general equilibrium models in which policy makers control market variables such as prices, quotas, import-export levies, etc. as was the case in most OECD member countries and especially in the European Union's Common Agricultural Policy (CAP).

Agricultural economics emerged as a field of applied economics that dealt with agricultural production, the transformation of food and fibre and their consumption. The practice of agricultural economics has maintained a distinct operational quantitative flavour and it has focused on practical problems such as decision-making processes (farms, companies, consumers), but decision-support models continued to be based upon general equilibrium models in which policy-makers control market variables, and this was the main tool used by policy-makers.

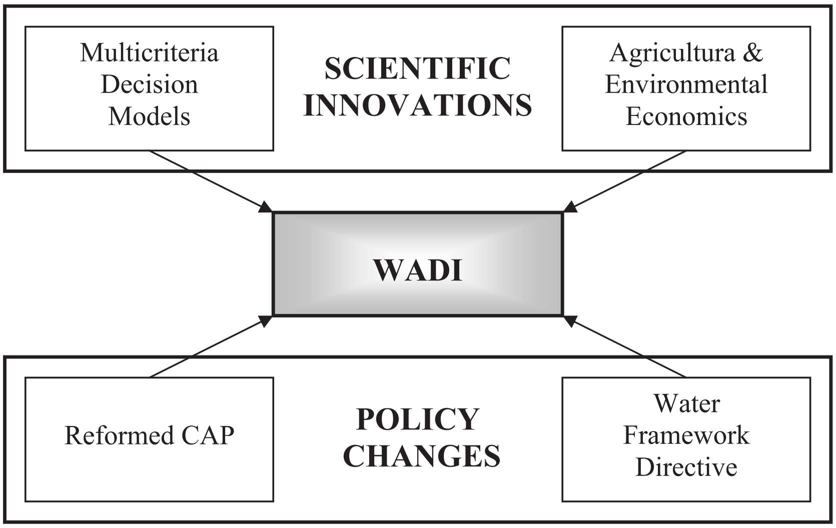
The general development of society (economic, social, technological) has changed policy priorities. As a result, in this changing academic and policy environment old simulation tools based upon market equilibrium models became only a partial solution, particularly when non-market variables and ecological impacts appear to be at the top of the agenda. For this reason, databases such as FADN need to be updated with new variables and methodologies if they are to be able to capture interactions between farming and the environment.

Diversity in farming systems also appears to be greater than ever, as conventional farming faces organic farming, and a wide range of new technologies (Genetically Modified Organisms, etc.) are competing in consumer markets, while global equilibrium may not reflect diversity in the adaptation of strategies and the impact of measures.

2. BASIC PREMISES OF WADI

The original design of the WADI project involved convergence in methods, research interest and policy priorities. Figure 2.1 shows the convergence of factors that brought this consortium of researchers together.

Figure 2.1.



We have justified the changing focus of agricultural economics from a narrow productive paradigm to a wider natural resources and environmental perspective. The name of the project is related to the policy objective (**Wa**ter Framework **Di**rective), but is also a tribute to the legacy of Arabic culture in Spanish and Mediterranean regions, *Wadi* meaning river or watercourse.

We have employed a fairly pragmatic approach, in which our final goal was to build a simple model of irrigated agriculture capable of simulating changing policy scenarios and measuring the impact of changes on social, economic and environmental indicators.

The use of water and water resources has been the focus of European Union (EU) Water Policy since the 1960s, as can be deduced from policy priorities, but water quality assurance is currently at the top of the Environmental Policy Agenda in the form of a new integrated approach. In 1995 the European Commission and Parliament launched the process of developing a Common Policy on Water, as part of Article 130R of the Treaty of the Union that empowers Brussels to protect the environment.

Directive 2000/60/EC of the European Parliament and the Council, which established a framework for Community action in the field of water policy, was adopted on October 23, 2000 and published in the Official Journal of the European Community on December 22, 2000. It is known as the Water Framework Directive (WFD).

This document identifies short-term and long-term research priorities as proposed by the members of WADI research consortium for supporting the implementation of the WFD, especially in the field of social sciences. The document was discussed at the final meeting of the WADI consortium in January 2004, three years after the approval of the WFD and after some countries had already incorporated the WFD in their national legislation.

We have attempted to identify the long- and short-term needs of support for the Commission and national authorities, and to comment on some of the points open to discussion in the WFD text. Nevertheless, this document has also been written for non-specialists. An element of introduction is therefore needed for general readers.

Analysis of the effects of water pricing on irrigated agriculture and farmers' behaviour ought to be an important research topic for European agricultural and environmental economists. The WADI project has established a methodology for the study of the interrelationships between agricultural and water policies and of their individual and joint influence on agricultural irrigation systems. This methodology, based on Multi-Criteria Decision-Making Theory, has been implemented in a real irrigation system, enabling us to build a model that allows us to:

a) Analyse how the recent CAP reform has influenced the water demand function and how hypothetical new reforms would affect the irrigation unit studied.
b) Measure the impact of the hypothetical total costs proposed by the WFD.

The various effects of the WFD and CAP on irrigated areas can be found in Berbel and Gómez-Limón (2000), which deals with the former, and Gómez-Limón and Arriaza (2000), on the latter, based on the same area. The conclusions that can be drawn from these studies lead us to hypothesise that there is a contradiction between these two policies: on one hand, the CAP reforms attempt to favour free trade and the competitiveness of EU agriculture (even if this goal is not fully achieved by policy-makers), while on the other, the WFD may impose additional costs on irrigated farming, negatively affecting its competitiveness.

However, we have tried to focus the attention of this report on WFD implementation, and we analyse how agricultural activities and water management legislation influence each other. More specifically, we focus on the water used by irrigation. European irrigated agriculture is very important in terms of area, product value and employment, especially in certain Mediterranean regions that are devoted to continental agriculture. This working paper analyses the impact of the Water Framework Directive (WFD) on irrigated agriculture with reference to the reformed CAP, which is a major factor in explaining the behaviour and future of agriculture, and we note the need for a more in-depth analysis and understanding of the complex links between agricultural and environmental policies when these are applied to irrigated agriculture.

From the methodological point of view, as chapter 5 explains, we base our approach on Multi-Criteria Decision-Making Theory. Hayashi (2000) reviewed multiple-criteria programming as applied to whole farm planning and regional agricultural planning. Researchers in agricultural economics or farm management are more familiar with these planning problems using linear programming than with selection problems discussed earlier.

The purpose of the use of multiple-criteria programming is twofold. (1) To plan more practicable farming, it is necessary to introduce labour-related and other objectives. (2) To make plans more realistic, it is essential to use the objectives that concern subsistence (self-sufficiency and the production for socio-cultural purposes), especially in developing countries. But our approach is quite innovative as it aims to provide descriptive models rather than normative farm or regional planning, as do most of the models found in literature (see Hayashi, 2000 or Romero and Rehman, 2003, for good reviews of this type of model).

A number of publications support the methodology and results that this report summarises. Peer-reviewed journals in which our authors have published during the project development (2000-2004) include the following:

- Agricultural Economics
- Agricultural Economics Review
- Agricultural Systems
- Australian Journal of Agricultural and Resources Economics
- Environmental Modelling and Software
- European Journal of Operational Research
- European Review of Agricultural Economics
- Journal of Agricultural Economics
- Journal of Environmental Planning and Management
- Water Resources Research

In these journals, some papers cover methodological developments (multicriteria descriptive models, multi-period programming, multi-attribute models of demand and markets), while others have focused on empirical results (scenario analysis, analysis of water pricing as an instrument, etc.).

A good number of high-quality papers have also been published in national or international sources which are not included in the research information Science Citation Index.

- Cuadernos de Economía
- Cadernos de Economia
- Estudios de Economía Aplicada
- L'informatore Agrario
- Nuovo Diritto Agrario
- Progetto Panda MIPAF.
- Revista Andalucía Geográfica.
- Revista da Sociedade de Ciências Agrárias de Portugal.
- Revista de Estudios Agrosociales y Pesqueros

Finally, a number of posters and papers have been contributed to a large number of conferences (international and national) in the fields of agricultural economics, engineering and operational research. In conclusion, we believe that the influence of the WADI consortium in the agricultural economics discipline will be realised in the years to come, as will that of books covering workshops on the Wadi project. All of this underlines the scientific quality of the results we present here.

3. THE PRACTICAL OBJECTIVE

As scientists we have a practical orientation in our work, and although our models are multipurpose in nature and can be applied to a wide range of decision-making problems, we focus on the top priority on the European policy agenda. Therefore

The general objective of the project is to analyse the sustainability of irrigated agriculture in Europe in the context of post-Agenda 2000 CAP Reform and of Framework Directive on Water.

The methodology developed is expected to be implemented in the various areas analysed, in order to evaluate the impact of the scenarios defined on their sustainability. In this sense it can be shown that the responses of agricultural irrigated systems to horizontal policies (CAP-2000 and WFD) are significantly different.

4. The Core Of The Project

Before the proposed methodology can be discussed, a brief presentation of the elements on which it is based is required: i.e. the farmers' multi-criteria behaviour and the classification (aggregation) of farmers into homogeneous groups.

4.1. Mathematical models and farmers' behaviour

The core of the WADI project is the model and its basic assumptions. The focus of our attention is the individual decision-maker (farmer), who faces a choice involving uncertainty about outcomes. Our farmer is not an economic automaton; he or she makes a choice among different priorities.

Regarding the nature of the model, our aim has been to build good 'descriptive' models based upon the multicriteria nature of decision-making, and the search for a compromise between the conflicting objectives of the farmer.

The success of irrigation schemes depends on how producers value water and on their willingness to pay for it. The utility of irrigation water to farmers, and thus the demand for it, is in terms of inputs (intermediate good) required to produce the end products demanded by consumers. The willingness to pay for water depends upon the value of the output over the cost of producing that extra output (value of the marginal product of water).

A number of approaches have been made to approximating the value of irrigation water. We may quote Kulshrehtha and Tewari (1991), who offer a classification of different approaches, and finally select the single-period Linear Programming (LP) Model to analyse a case study. If sufficient data can be obtained at a reasonable cost, Linear Programming has several advantages over other methods.

Agricultural models usually maximise profit - estimated as gross margin - as their single objective. LP has been widely used to solve companies' resource allocation problems. The model's ability to predict how companies adjust to changes under the influence of a variety of exogenous factors is well known, and particularly when used at company level, aggregation problems can be avoided.

Traditional mathematical programming based on the optimisation of a single objective may be broadened by multicriteria analysis. There are two main types of multicriteria technique: multiobjective programming, which tries to simultaneously optimise several objectives (often with many of them in conflict), and goal programming, which tries to satisfy as far as possible a set of goals compatible with the preferences exhibited by farmers.

The interest of using multicriteria decision-making models (MCDM) methods in the context of the problem analysed here can be deduced from the variety of criteria that are taken into account by farmers (agricultural decision-makers) when they are planning their productive activities. Thus resource allocation in farming (land, labour, water, etc.) implies the simultaneous optimisation of several conflicting criteria, and the simulation of more realistic decision-making processes will lead to a closer scenario simulation and consequently to better policy-making procedures. Evidence in favour of these affirmations can be consulted in Gasson (1973), Cary and Holmes (1982), Sumpsi *et al*. (1997), Gómez-Limón and Berbel (1995) and Amador *et al*. (1998).

However, in this project we wish to look into more realistic models that combine the advantages of LP, i.e. simplicity and flexibility, with the integrative ability of MCDM. For the reader interested in MCDM theory, we suggest Romero and Rehman (2003), for a review of multicriteria paradigms in agricultural economics.

More specifically, it is worth noting that our modelling approach is based on the estimation of particular farmers' multi-attribute utility functions (MAUF) and that we devote our modelling efforts to the task of description. Descriptive models are evaluated by their empirical validity, in other words, by the extent to which they correspond to observed choices.

4.2. Aggregation bias and cluster analysis

By modelling particular farmers' behaviour through the above-mentioned MDCM approach, we can a obtain reasonably good approximation to real individual decision making. Nevertheless, the objective of the Wadi project is to obtain aggregated results in order to guide policy making. This is why aggregation of individual results is a key issue in this project.

Modelling agricultural systems at any level other than that of the individual farm implies problems of aggregation bias. The introduction of a set of farms in a unique programming model overestimates the mobility of resources among production units, allowing combinations of resources that are not possible in the real world. The final result of these models is that the value obtained for the objective function is biased upward and the values obtained for decision variables tend to be unachievable in real life (Hazell and Norton, 1986, p. 145).

This aggregation bias can only be avoided if the farms included in the models fulfil strict criteria regarding homogeneity (Day, 1963): technological homogeneity (same possibilities of production, same type of resources, same technological level and same management capacity), pecuniary proportionality (proportional profit expectations for each crop) and institutional proportionality (availability of resources to the individual farm proportional to average availability).

The cases studied for the Wadi project are a set of irrigated areas ranging from 1,000 to 10,000 hectares. These are relatively small areas that can be regarded as fairly homogeneous in terms of soil quality and climate, and in which the same range of crops can be cultivated with similar yields. Furthermore, the whole set of farms that are integrated into this agricultural system operates the same technology at a similar level of mechanization. Given these conditions, it can be assumed that the requirements regarding technological homogeneity and pecuniary proportionality are basically fulfilled.

Given efficient capital and labour markets, the constraints included in modelling these systems have been limited to agronomic requirements (crop rotations) and the restrictions imposed by the CAP (land set-aside, sugar-beet quotas, etc.) that are similar for all farms. The requirement of institutional proportionality may thus also be regarded as having been met.

We thus conclude that the agricultural systems in question can be modelled by means of a unique linear program with relatively small problems of aggregation bias. Numerous studies with similar units of analysis have been based on this kind of aggregate model, e.g. Bernard et al. (1988), Chaudhry and Young (1989), Kulshrehtha and Tewari (1991), Varela-Ortega et al. (1998), Berbel and Gómez-Limón (1999).

However, it is essential to note that the requirements discussed above are based on the assumption that the sole criterion on which decisions are based is profit maximisation. If a multi-criteria perspective is being considered, an additional homogeneity requirement emerges in order to avoid aggregation bias; viz., homogeneity related to choice criteria. This kind of similarity has been implicitly assumed in studies based on a unique multi-criteria model for the whole set of farmers in the areas being analysed (for example, Gómez-Limón and Berbel, 1999).

Nevertheless, we suspect that the decision criterion of farmer homogeneity does not reflect the normal situation in real agricultural systems. This suspicion, as we discuss below, has been confirmed by a survey of the areas analysed. In fact, the decision criteria are primarily based on psychological characteristics of the decision-makers, which differ significantly from farmer to farmer. According to this perspective, the differences in decision-making (crop mix) among farmers in the same production area must be primarily due to differences in their objective functions (in which the weightings given to different criteria are condensed), rather than other differences related to the profits of economic activities or disparities in resource requirements or endowments.

In order to avoid aggregation bias resulting from lumping together farmers with significantly different objective functions, a classification of all farmers into homogeneous groups with similar decision-making behaviour (objective functions) is required. For this issue we have taken the work of Berbel and Rodríguez (1998) as a starting point. These authors noted that for this type of classification the most efficient method is cluster analysis, taking farmers' real decision-making vectors (actual crop mix) as the classification criterion.

The term 'cluster analysis' embraces a loosely structured body of algorithms, which are used in the exploration of data from the measurement of a number of characteristics for a collection of observations. Cluster analysis is concerned with the discovery of groups. The word 'cluster' or 'group' should be interpreted as a collection of 'similar' objects. In our case, the objects are farmers operating in a particular irrigated area, randomly sampled (34 producers).

In order to obtain homogeneous groups with similar decision-making behaviour, the cluster analysis should be performed using the relative importance of the different management criteria regarded by farmers as classification variables. Unfortunately, as shown by Berbel and Rodríguez (1998), these data, obtained through verbal questioning, represent only poorly the real weightings that are taken into account by farmers. This may be because management criteria are not well understood by farmers. Deffontaines and Petit (1985) claim that farmers' criteria are better observed by indirect methods than by direct questioning. Thus, the sample of farmers needs to be grouped according to variables that can be regarded as proxies for the relative importance of management criteria.

We assume that in a homogeneous area the differences in the crop mix among farmers are mainly caused by their different management criteria (utility functions) rather than by other constraints such as land quality, capital, labour or water availability. Thus, the area (as a percentage) devoted to the different crops (proxies of the real criteria) is used as a classification variable to group farmers using the cluster technique.

Note that the homogeneous groups obtained in this way can be regarded as 'fixed' in the short and medium terms. As noted above, the decision criteria are based on psychological features of the decision-makers, which is why they may be regarded as producers' structural characteristics. These psychological features, and thus the criteria, are unlikely to change in the near future. This means that the selection variables chosen allow farmers to be grouped into clusters that are robust to changes in the policy framework (i.e. water pricing). In other words, once the homogeneous groups of producers have been defined for actual data (crop mix), we can assume that all elements (farmers) within each group will behave in a similar way if policy variables change.

All the above makes the point that we consider homogenous groups as units of analysis that finally need to be aggregated to obtain global results at irrigated area and basin levels. These aggregated results are the ones that could help policy making.

5. THE METHODOLOGICAL APPROACH

5.1. Methodology diagram

Figure 2.2 summarises the conceptual paradigm that underlies the study.

According to this plan, the proposed methodology can be divided into five principal stages, as outlined below:

The first stage is the classification of farmers, which is done using cluster analysis as described above.

Once homogeneous groups of farmers have been defined, the second stage builds the mathematical models. For each cluster, a different multi-criteria model is developed in order to allow independent simulations based on the decision-making behaviour of the various groups of farmers to be run. For this purpose, the basic elements of any mathematical model; i.e. decision variables, objective function and set of constraints, have to be outlined. While the choice of crop areas as a decision variable does not cause any problem (observing crop diversity in the area studied is sufficient), the objective function and constraints require more detailed analysis. The objective function for each cluster is estimated using a multi-criteria procedure as described in the next section and data are gathered for the current situation (highly subsidised water price per unit of irrigated surface). Again, the estimated objective functions are assumed to be those that the farmers in each cluster will attempt to maximise in the future, under any policy scenario that they might face.

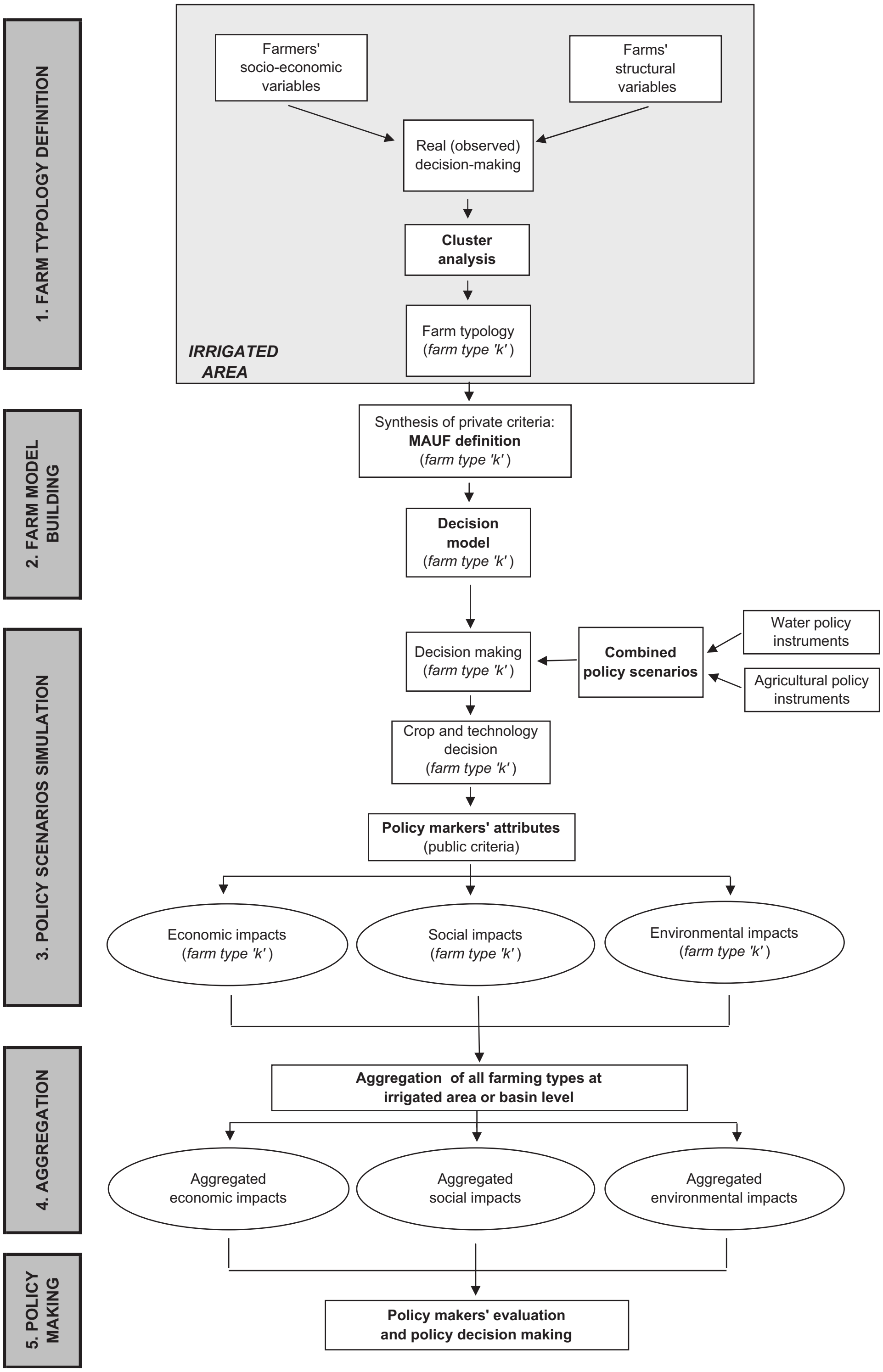
The constraints that need to be satisfied in the decision-making process are mainly due to the structural characteristics of the farms (climate, soil fertility, market limits, CAP requirements, etc.), that are basically identical for all. Only slight differences have been fixed by clusters according to the data obtained in the survey; these are mainly related to farm-type area and sugar-beet quotas.

The third stage of the study performs the simulations. Thus, based on the WFD implementation scenarios outlined above, the decisions taken, i.e. crop mixes, by the different clusters of irrigators were obtained.

The crop mixes obtained from the models are of little significance for agricultural and environmental policy-makers, who are primarily interested in a series of attributes that result from these crop mixes. These include economic attributes (farmers' income and the state's recovery of costs), social attributes (direct employment generated in the agricultural sector) and environmental attributes (water consumption and fertiliser consumption). The calculation of these attributes and the analysis of the efficiency of the economic instrument (water pricing) proposed forms the core of the fourth stage of our methodology.

Finally, aggregation of the results of the homogeneous is the fifth stage, ehich finally obtains the aggregated results used to advise policy-makers.

Figure 2.2. Methodology diagram



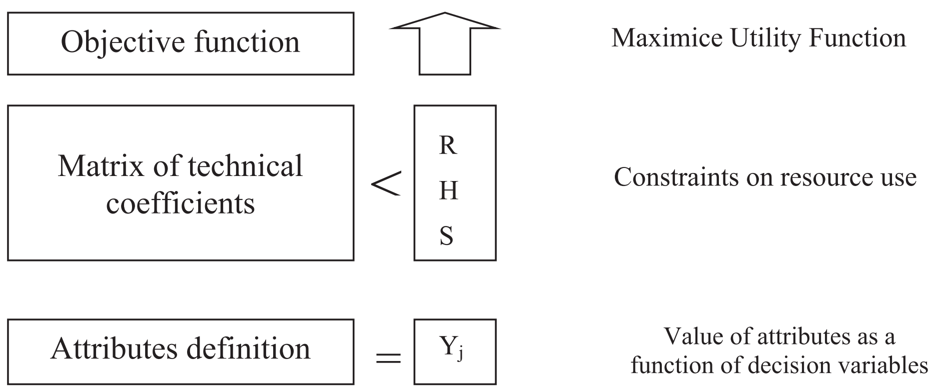
5.2. The models

We should mention that our decision-making model is based on farmers' objectives, but some of the attributes may also be objectives for policy makers (social, environmental, economical). Unfortunately for them, society suffers externalities from farmers but the only relevant objectives in the crop plan are the attributes relevant for the farmer himself, which are located explicitly in the first row of the model (objective function).

Attribute values are thus an output of the model but do not influence decision-making in itself.

Chapter 4 also fully develops the model, including its constraints and attributes which, as mentioned above, have been tailored to each farm type in every selected location. Some of the project partners have selected their farm types by means of expert assessments based upon farm size and orientation, but in most cases the selection is the result of cluster analysis of farmer questionnaires.

Figure 2.3. Decision-making model



5.3. Policy marker's relevant attributes

Changes in the European institutional framework will determine whether the various parameters related to sustainability will also be modified:

- Economic (rural incomes)
- Social (rural employment and population)
- Environmental (pollution, water demand, etc.)

In order to measure sustainability, however, we need to develop practical indicators, and we have also done this, since the OECD (1999) has proposed a set of indicators to check the sustainability of agricultural practices.

Van der Weft & Petit (2002), in a recent review of environmental indicators, explain that agricultural indicators may be based on farmers' production practices ('means-based') or on the effects of these practices ('effect-based') on the state of farming. For example, in order to measure the impact of farmer's decisions on quality of groundwater we consider nitrogen balance as a 'means-based' measure, while nitrate lost to groundwater is 'effect-based'. Although the link is indirect, our model attempts to acquire an understanding of the pressures involved, and the conversion of this pressures to ecosystem impact would require a complex multidisciplinary model that lies out of the scope of our research.

The aim of this section is to select a limited number of parameters that can be fed into the mathematical models in order to evaluate the impact on irrigated agriculture of various policy scenarios. The model uses the following subset of OECD sustainability indicators (OECD, 2001; Pierr, 2003).

We finally selected the following list:

- Economic balance: Farm income, Farm, Contribution to GDP, Public support.
- Social impact: Farm employment, Seasonality.
- Landscape and biodiversity: Genetic diversity, Soil cover.
- Water use: Irrigation technology, Water use, Marginal value of water.
- Nutrients and pollutants: Nitrogen balance, Pesticide risk, Energy balance.

Chapter 5 explains in more detail how these parameters were computed, and this is a point where we benefit from the use of the multicriteria paradigm as this defines its concepts into a model that we can review.

5.4. Policy scenarios

A wide range of methodologies may be utilised to build a model to simulate various scenarios, and reviews of such processes can be found elsewhere. Mathematical programming has been widely used for this purpose, and is frequently used for policy simulation. Examples of the use by the European Commission of agricultural sector modelling for medium-term forecasting and system simulation based on mathematical programming can be found in European Commission (2000, 2001) and Heckelei and Britz (2001), which is an example of how a model can be used as a tool for generating medium-term projections for the agricultural sectors of EU member states and the impact of alternative CAP scenarios.

In any case, as we explain in depth in chapter 3, scenario definition is another key aspect of the Wadi project. These scenarios reflect both the future implementation of the WFD and the foreseeable development of the CAP. As has been commented above, the WFD requires member states to introduce water prices that integrate the "polluter pays principle" (PPP); thus, raising the price will induce the user to make more rational use of water. Thus, different scenarios will suggest different degrees of cost recovery. Along the same lines, future CAP reforms should be taken into account in the characterization of these scenarios.

5.5. Methodological approach summary

Table 2.1 summarises our approach versus classical modelling techniques.

Table 2.1. Characteristics of our methodology.

CLASSIC	**OUR APPROACH**
Profit maximizing	MCDM Utility
Homogeneous behaviour	Farmer type specification
Focus on farm	Focus on farmer
Macromodels	Micromodel aggregation
Economic activity	Indicators and multifunctionality
Short-run analysis	Long-run analysis based on scenarios

6. THE EUROPEAN DIMENSION OF THE PROJECT. THE CASE STUDIES

The research was designed to exploit the potential benefits of the European dimension of the project, by running a number of case studies in different countries, using the same methodological approach illustrated above and in chapters 4 and 5 (table 2.2 summarises the areas under study).

Table 2.2. The case studies

Greece	Pella Larisa Xanthi
Italy	Mantova Ferrara Ravenna Foggia Catania
Portugal	Baixo Alentejo Lezìria do Tejo Baixo Montego
Spain	Duero Guadalquivir
UK	England and Wales

This enables us to compare different environmental and institutional conditions and to verify the different behaviour of farming systems *vis-à-vis* the application of the WFD and CAP reform.

This is particularly relevant when studying policy issues that imply strong adaptation to local conditions and require institutional compatibility related to very specific local issues.

The use of case studies in combination with European-wide scenarios also enables us to combine an understanding of common problems brought about by the application of WFD all over Europe with locally related issues. Furthermore, it allows the analysis of the interaction of a number of policy and non-policy factors at local system level.

The experience of WADI has proved that different farming systems result in wide differences in:

- Water demand and related socio-environmental performance

- Economic/environmental fragility due to the context in which they are located.

For this reason, typologies of irrigated farming system may be defined in order to identify locally appropriate strategies. In particular, the social and environmental roles of agriculture should be emphasised in relation to each local context, in order to ensure consistency with CAP and rural development policies.

3.

Water Framework Directive and irrigation

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1. The Importance Of Irrigation In Europe

Irrigation will be a determinant use in many regions of Europe regarding the WFD, through its requirements to characterise water use, adopt full costs recovery, implementation of incentive pricing. Implementation of the WFD will have a major effect on the management of irrigation management where this is a major use. This is the case in many parts of the southern Mediterranean, where irrigation can account for over 70% of total annual abstraction.

Irrigated agriculture provides about 40% of the world's food supply, but occupies only 17% of the arable area of the planet (FAO, 1999). Some scenarios predict an increase in cereal demand of around 40% for 2020, for which reason global pressures on water will increase all over the world.

In the Mediterranean countries irrigation accounts for about for about 83% of total water demand in Greece, 57% in Italy, 68% in Spain and 52% in Portugal. This is in marked contrast to northern and Eastern European Countries where, on average, less than 10% of water resources are used for irrigation. The volume of irrigation water applied depends on climate, the crop being cultivated, the area being irrigated and the method of application. Nationally the area under irrigation varies greatly in absolute terms and in terms of percentage of total agricultural area, partially reflecting differences in climate. Thus irrigated land varies from one or two percent in many Central and Northern European countries up to 38% in Greece. With a total irrigated surface in the EU-15 of about 11.3 million hectares and total agricultural water use around 73,000 million m^3/year. European average water use for irrigation is 6,500 m^3/ha/year. Over the past few decades the trend in agricultural water use has been tending to rise due to increasing irrigated area. Most recently, however, the rate of growth of the irrigated area has been diminishing in several countries.

A unique feature of the Mediterranean is that water is a key limiting condition for sustainable development, increased quality of life and peace. Recognizing the seriousness of the situation, it is necessary to consider what appropriate solutions might be developed while we continue to work on all factors likely to reduce pressure on water resources and avoid irreversible damage.

Irrigation systems have been the basis for human settlement and development in Europe and the Mediterranean since Rome ruled the world (the western part of Europe), and we can look back on a long history of hydraulic works, technological improvements and institutional frameworks for modifying natural water flows in rivers and underground sources, integrating utilities that control water delivery in terms of time and location into the natural water regime. The main result of this has been the creation of an impressive irrigation system during the last 2000 years. For the past 50 years, irrigation development has often featured in strategies for rural development through improved agricultural production. More recently however, in the context of changing priorities and concerns about the impact of intensive agriculture, the emphasis has switched to sustainable solutions which balance economic, social and environmental objectives.

Agriculture in the EU-15 is one of the three important water sectors of water use, besides industry and urban use. In some member states agriculture is the leading human use of water and rises to 80%. Agriculture thus influences the availability of water, while agricultural activities can have a strong influence on water quality through the impact of diffuse pollution. On the other hand, European water legislation is regulating the use of water and therefore is relevant to agricultural activities

While irrigation is an ancient practice, the amount of agricultural land under irrigation has increased enormously during the second half of the past century. In the European Union (EU-15), the irrigated area grew from nearly 6.5 million ha in 1961 to 11.6 million ha in 1996 as a whole, as a result of both public and private investment. However, this growing area will be affected by Directive 2000/60/EC.

However, the contribution of irrigated agriculture to world food production and European agriculture has been accompanied by significant environmental costs. In addition to being a major water user, irrigated agriculture is also an important source of water-related environmental problems. Reservoirs constructed to supply water to agriculture and other sectors have destroyed significant natural assets by inundation. Dams and diversions present physical barriers to fish migration, alter stream flow regimes and water temperature, and trap sediments. Consequences include severe degradation of aquatic and riparian habitats, with significant threats to aquatic species. Surface return flows and drainage from irrigated agriculture carry salts, fertilizers, pesticides and other pollutants into surface waters, causing harm to fish and wildlife, and degrading water for human uses. Aquifers used for drinking water are also contaminated by agricultural pesticides and nitrogen when irrigation water percolates through the ground into the saturated zone[2].

Irrigation is not the only responsible agent, but one of the biggest driving forces and pressures on water resources is agriculture and changes in practices. On average, agriculture accounts for about 2.3% of the Gross Domestic Product (GDP) of EU-15 Member States. Percentages, however, vary considerably from 1% in Germany and the UK to about 12% in Greece. In most countries these percentages have been falling during the past few decades, reflecting the relative decrease in the importance of agriculture in comparison to other economic sectors. However agriculture is still a very important economic sector in the EU Accession Countries.

Pressures on agriculture water use may therefore increase in Eastern Europe, where agricultural water demand has been falling as a result of economic problems and changes in land ownership. Generally speaking, a major influence on the increase in irrigated land in the EU has been the Common Agricultural Policy, which controls the type and quantity of crops grown.

2. THE FUTURE OF THE CAP

The history of the CAP has always been one of adaptation to internal and external forces on the agricultural sector. There has been a long series of modifications to policy goals and instruments in reaction to the changing agricultural environment. The latest significant changes were adopted in 1999 as part of the Agenda 2000 framework, which aims to solve internal (justification of social support) and external (the next WTO round and EU enlargement) problems (Buckwell, 1997). These problems were addressed in the Agenda 2000 Reform that continues the 1992 Reform in the sense of progressing in the direction of institutional prices that are in line with world prices (i.e. lower) and compensating for this reduction by direct payments to farmers. Some experts have criticised this reform as being too timid and for not providing an adequate solution to these problems.

The latest reform (2003) is the result of the following driving forces:

- Consumer demand for sustainable agriculture that guarantees healthy and safe food
- External pressures on opening markets and free trade
- Budgetary constraints

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[2] In addition to these impacts on water resources and related ecosystems, irrigated agriculture has an ancient foe: salinization of irrigated soils. Dissolved salts introduced by the application of irrigation waters are progressively concentrated by evaporation and plant transpiration. If these salts are allowed to accumulate in the root zone, agricultural productivity falls. When these salts are leached beyond the root zone, ground water quality and downstream surface quality can be impaired. Thus salinity constitutes both an on-farm management problem for irrigators and an off-farm externality for other water and environment users

These factors produced a deep-going reform of CAP in the direction of a more decoupled policy with internal prices that are more in line with world prices and compensation for this reduction in the form of direct payments to farmers. the main lines of the reform are:

- Decoupling support from production
- Modulation of farm support.

This drivers and results of Reform 2003 imply a certain nationalization of the CAP, withimportant impacts on markets and regional cohesion, and uncertainties for farming systems. In this new scenario agricultural sectors with higher productivity will be affected more severely than low-input agriculture, and irrigated agriculture will be therefore severely jeopardised because:

- Irrigation is relatively intensive in energy, chemicals and labour, and some products (cereals, sugar beet) may not be competitive under international competition and price conditions
- The supply of 'environmental goods' is not so clearly justified in irrigation as it may be argued to be in extensive low-input agriculture.

Table 3.1 summarises the changes in agricultural policy priorities.

Table 3.1: Priorities of CAP policy

	Issues and concerns	**Objectives**	**Agricultural water pricing**
In the past	Poverty in rural areas	Equity & rural development	Lower prices
	Increasing food demand	Food self-sufficiency	
Future	Water and soil pollution	Sustainable development	Higher prices
	Budgetary constraints	Economic efficiency	

However, increasing the water supply for irrigation has been subjected to rising marginal costs and recently also to growing concern about the environmental impact of water use. Improvements aimed at getting as much as possible out of limited resources can be seen in the growing importance of drip irrigation. But irrigation is not the only user of water, and human activities and population have a higher priority when scarcity appears (as is the rule rather than the exception in many Mediterranean regions), which implies:

- guaranteeing sufficient, regular and safe water supplies
- efficient and effective water distribution systems
- equitable use of shared water resources in transborder systems.

Such an emphasis entails four key activities: comprehensive water policy and integrated planning; improving water consumption by users and uses; advanced water treatment, re-use and energy implications; and plant breeding for efficient water and nutrient use.

All the items addressed should be guided by local scale problems and socio-economic considerations, including a cost/benefit ratio for technology products that will be acceptable to Mediterranean countries, considering the enormous range of Mediterranean climates and agriculture systems. The importance and range of consumption of water for agriculture can be shown if we note that the average productivity of water for agriculture in Spain moves between 3 eurocents (extensive sugar beet, cereals in continental Spain) to more than 1 €/m^3 (greenhouse crops in the south-east of the country).

3. HISTORY OF EUROPEAN UNION WATER POLICY

Protection of the environment has been a key theme of EU legislation. For example, the Maastricht Treaty (1987) made specific reference to environmental protection, safeguarding human health and achieving sustainable development. This was specifically agreed in Article 130-R '*Community policy on the environment shall aim at a high level of protection taking into account the diversity of situations in the various regions of the Community'*.

But before the Treaty of the Union was signed, environmental policy objectives have been apparent in various types of legal acts. The first type consisted of directives that set quality objectives for water for a specific use, such as drinking water. These include:

- Quality of water intended for human consumption (807778/EEC).
- Water intended for the abstraction of drinking water (75/440/EEC).
- Quality of bathing water (76/160/ECC).
- Freshwater Fish (78/659/EEC). The Directive 78/659 regulates the quality of continental water when the life of fish needs protection or improvement. This rule appears in Spains Law by Royal Decree 927/88.
- Quality required of shellfish waters (79/923/ECC).

A second type of legal act sets Emission Limit Values for certain substances, such as:

- Pollution caused by certain dangerous substances discharged into the aquatic environment (76/464/EEC) and daughter directives;
- Urban waste water treatment (91/271/EEC);
- Protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC) and,
- Placing of plant protection products on the market (91/414/EEC).

These directives tackled pollution from point sources (i.e. dangerous industrial substances, urban waste water) and diffuse sources (i.e. agricultural nitrates and pesticides). They aimed to protect water against pollution. However, it obvious that appropriate reductions in activities that actually cause pollution are needed in order to reduce pollution and thereby meet Emission Limit Values.

During the 1980s and early 1990s it was apparent that increased abstraction of and discharges to water were the cause of rapidly deteriorating water resources, with consequences for ecological systems and human populations. These concerns were expressed for example in the

Dublin Accord on Water which laid a commitment to sustainable water resource management. The Accord also promoted the idea that water should be promoted as an economic commodity rather than be treated as a free good to be squandered with impunity: it is increasingly scarce, valuable, and expensive to provide.

By the mid-80s it was accepted that more comprehensive strategies were necessary to regulate the use of natural water resources. Thus the 1990s saw the emergence of ‘horizontal’ directives to regulate potentially environmentally damaging activities. In this context, a third type of legislation which promoted an integrative approach was developed. The Integrated Pollution Prevention and Control Directive (96/61/EC) is one of the main policy instruments designed to prevent, and where this is not practical, to minimise, emissions to land, air and water. The IPPC, however, applies only to selected industrial (and intensive livestock farming) activities which are perceived as presenting particular environmental hazards.

In this context, and given the numerous unresolved problems that were encountered during the implementation of the earlier aforementioned Community water directives in the Member States, the European Council of Ministers asked for a reform of the water Policy. The European Parliament and Council adopted the Water Framework Directive in September 2000, and it was published in December 2000 (Council 2000).

4. FUNDAMENTALS OF WFD

The Directive aims to establish a framework for the management and protection of water on the basis of individual river basin districts. It is intended to play a strategic and fundamental role in the area of water policy. It sets ambitious objectives for the preservation and restoration of the status of bodies of surface and ground water.

Many issues have created barriers to early agreement on WFD, but one of the most difficult has probably been Article 9 in the first drafts of the proposal, which originally obliged EU members to charge the full cost of water to users. The final agreement was much vaguer, establishing merely that EU members should try to recover all water service costs, including environmental costs, in accordance with the “polluter pays” principle.

The main objective of WFD is the sustainable use of water through the long-term protection of resources. But a possible source of conflict is the omission of other objectives such as balanced regional development (e.g. Art. 40 of the Spanish Water Act). We may define WFD as a environmental norm rather than a general regulation instrument. Furthermore, there is very little reference to flood prevention (important to all member states) and drought management, which is essential to Mediterranean countries.

The Water Framework Directive outlines an overall strategy for water management in Europe and formulates environmental objectives for all European water bodies. It also seeks to simplify preceding legislation in order to ensure that water policy will be more effective. It focuses much more on the sustainable management of water resources than did the previous legislation, including as it does the description of instruments needed to achieve the agreed aims.

With respect to the agricultural use of water for irrigation the Water Framework Directive mentions a number of important aspects, namely :

- River basin management, whereby water resources are managed at an integrated catchment level
- Cost recovery for water services, whereby those who benefit from using water (as a resource or a sink for waste) pay for such services, including the costs of environmental protection
- Participation of stakeholders in the planning and decision making process
- Protection of groundwater and wetlands.

The Water Framework Directive makes reference to flood and drought management, but in little detail, and it is left to member states to deal with these topics according to local circumstances: in the UK for example, the WFD will interact with Catchment Flood Management Plans, although it is not yet clear exactly how this will be done in practice and how these plans will be incorporated into river basin water management strategies. In some areas for example, water regimes have been heavily modified to reduce the risk of flooding of settlements; this can be positively affirmed in all member states.

An important aspect of the Directive is that, according to the principle of subsidiarity and the wish to keep regulations to a minimum (Rapport 1995), it is left to Member States to define quality objectives, e.g. “good ecological status” and to set targets for single river basins. Member States can go far beyond the minimum requirements set by the Water Framework Directive if they wish. Emission Limit Values are planned only for dangerous substances and these will be dealt with outside the WFD process.

In COM 477 (2000) more background is provided on how water pricing could be used for cost recovery purposes. Many references are made to agricultural water use and to cost components. For further analysis of this concept, readers should read the guide ‘Economics and the environment: the implementation challenge of the water framework directive: a guidance document’. This guide attempts to illustrate the requirement for cost recovery formulated in WFD as this is currently interpreted in the common strategy for the implementation of WFD.

5. CALENDAR AND WORKPLAN FOR WFD AND ECONOMICS

The WFD implementation plan implies a tight calendar and a demanding effort for agricultural economics.

As table 2.2 demonstrates, some of the milestones have economics as the integrating main discipline, but in fact, economics thinking underlies the whole implementation strategy, as we will see further on in this paper. Nevertheless, we have highlighted the activities that we believe may be more supported by social sciences.

Table 3.2. General timetable for the Directive

	Calendar
Dec. 2004	**Completion of the analysis of river basin district characteristics (Art. 5)**
	Establishment of the register of protected areas (Art. 6)
March 2005	State submits the overview of district characterisation to the Commission (Art.15)
Dec. 2006	Operational implementation of the first water status monitoring programme (Art. 8)
	National measurement of environmental quality standards for priority substances (Art. 16)
	Deadline for public consultation on the work programme (Art. 14)
Dec. 2007	**Deadline for public consultation on the principal problems (Art. 14)**
Dec. 2008	Deadline for public consultation on the draft management plan (Art. 14)
Dec. 2009	Publication of the programme of measures (Art. 11)
	Publication of the first management plan (Art. 13)
End 2010	**Implementation of an incentive-based pricing policy (Art. 9)**
	Operational implementation of the combined approach (Art. 10)
Dec. 2012	**Operational implementation of the programmes of measures (Art. 11)**
	Operational Implementation of the second water status monitoring programme (Art.11.8)
Dec. 2013	Completion of the second district characterisation programme (Art. 5).
Dec. 2015	Achievement of the objective of good status for water (Art. 4.1)
	1st re-examination of the programmes of measures (Art. 11)
	Publication of the 2nd management plan (Art. 13)
Dec. 2018	Operational implementation of the 3rd water status monitoring programme
Dec. 2019	Completion of the third district characterisation programme (Art. 5).
Dec. 2021	Deadline for the first extension related to achieving the objective on good status (Art. 4.4)
	2nd re-examination of the programmes of measures (Art. 11)
	Publication of the 3rd management plan (Art. 13)
Dec. 2027	Last deadline for achievement of the environmental objectives (Art. 4)2

6. KEY ASPECTS FOR 2004-2005

During the first years of implementation, Article 5 stipulates "*characteristics of the river basin district, review of the environmental impact of human activity and economic analysis of water use*".

We will review this article with special reference to its implications for the social sciences, but nevertheless we will briefly consider the needs of other sciences.

6.1. The technical elements used to characterise water bodies.

a - Defining the boundaries of water bodies. The Directive requires "water bodies" or "groups of water bodies" to be identified. It stipulates that an initial characterisation of surface water bodies and groundwater should be conducted. Water bodies at risk shall undergo further characterisation (both surface water and groundwater).

b - Other: including definition of coastal water and heavily modified water bodies

As the 2004 inventory is the first one to be produced, more detailed characterisation of water bodies is not required at this stage.

6.2. Analysis of pressures, impacts and water use

This analysis of pressures, impact and water use will be conducted as follows:

a - Collecting the data available on water usage, from both a technical and economic point of view.

b - Evaluating *pressures* on environments The usages identified above cause pressure on environments. These are the "driving forces" behind these pressures.

c - Identifying *impacts* on the status of water bodies The impact of pressures on the status of water bodies is evaluated. However, there is no obligation to use modelling when constructing the inventory.

d - Identifying *water use*.

6.3. Economic analysis of water use

The inventory document will provide economic data on water usage. Under Article 9, water-pricing methods and investment funding channels are to be described, and applications of the principle of recovery of the costs of water services reported on.

6.4. Scenario analysis

a - The baseline scenario.

b - Evaluating pressures and impacts in the year 2015

The Water Framework Directive requires river basin management plans to be drawn up by 2009 for achieving good water status by 2015. Although the assessment of the actual situation in terms of pressures, impacts and water status is the key to the preparation of these plans and the identification of programmes of measures, it is important to ensure that changes that will take place during the next 9-15 years are taken sufficiently into account in the analysis and identification of measures. The final aim of this analysis, ***which combines both economic and technical expertise***, is the answer to the following question: *where will we be in terms of water status in 2015?.*

6.5. Public consultation

Each river basin committee is responsible for drawing up the timetable and the information and consultation procedures to be conducted in 2004-2005 and specifically, in 2004, to prepare for public consultation by providing information on water management and the current situation.

Public consultation on the *significant issues* identified and the *work timetable* will thus require prior dissemination of information on water management that is sufficiently global in approach and can be understood by laypeople.

The programme of measures (Article 11), to be drawn up between now and the end of 2009, will define the statutory provisions or basic measures to be implemented for each district in order to achieve the objectives defined for 2015 by the management plan under Community and/or national legislation (for example: extension of sensitive areas or vulnerable areas, reporting and authorisation system, definition of resource protection areas, discharge control, etc.). These measures also include the pricing provisions created to encourage users to manage water better. Measures can be drawn up at national level.

If the provisions above are not sufficient to fulfil the objectives set, supplementary measures must be implemented. The Directive provides a non-exclusive list of these. These either strengthen the basic measures or take the form of new provisions such as codes of good practice, voluntary agreements, economic and fiscal instruments, provision of information to users, etc.

7. ANALYSIS OF KEY ECONOMIC ELEMENTS FOR COST RECOVERY OF WATER SERVICES IN THE WATER FRAMEWORK DIRECTIVE

7.1. Introduction

Water management is a European Policy priority. At the same time, use of water and water resources has been the focus of the European Union (EU) Water Policy since the 1960s. This section reviews the key economic elements of the Water Framework Directive.

The classical microeconomic view of water pricing focuses on the profit maximization assumption and input-derived analysis of demand. When water is treated like any other input, this may not recognise the social impact of irrigation, i.e. its contribution to rural development and employment in less favoured areas. On the environmental side, irrigation also helps to maintain certain minimum levels of population in sensitive areas and thus helps to slow down the progress of desertification in arid regions.

Some of these experiences can be found in OECD (1999), and research on Spanish cases can be found in Berbel and Gómez-Limón (2000) and Feijoó *et al*. (2000). These authors all argue that price increases force farmers to change their cropping patterns in the direction of less water-intensive crops, some of them heavily subsidised by the CAP, as opposed to labour-intensive irrigated crops. They also conclude that elasticity effects should be taken into consideration, finding that responses to price increases may only produce significant water savings when price is already severely affecting farmers' incomes.

It is also worth mentioning that two other domestic policies related to irrigation water have been recently approved in Spain, namely the creation of water markets (Water Act, 1999) and the modernisation of irrigation systems (National Irrigation Plan, 2001). Both measures, which are being implemented in order to improve the efficiency of water use, are due to be complemented by strengthened administrative rules. Nevertheless, this paper s focuses only on the two European policies indicated above. We might also mention measures taken by other EU members that have also reformed legislation involved in water management in agriculture, such as Italy; 'Decree 152/99 sulle acque', that also anticipate Directive 60/2000.

7.2. Economic analysis of WFD

The inventory document will provide economic data on water usage. Under Article 9, water-pricing methods and investment funding methods are described, and application of the principle of recovery of the costs of water services reported on.

This economic analysis due for 2004 must be focused on valuation of water use, forecasting supply and demand for water and general cost inventory.

The economic analysis of water use is an important element of WFD. How to execute the economic analysis is not well defined in the WFD. However, in the common strategy for the implementation of WFD, guidance is under development. The WATECO reference committee (see WATECO 2003) has developed a guide to the process of introducing economics into WFD.

Article 9 requires Member States to take the principle of recovery of the costs of water services into account. At the same time, article 5 and related articles (i.e. 4, 11 and 13), and Annex III, show what should be entitled “Theoretical Economic Analysis of Water Use”.

Article 2, paragraph 38, defines water services as follows:

> *“All services which provide, for households, public institutions or any economic activity: (a) abstraction, impoundment, storage, treatment and distribution of surface water or groundwater, (b) waste-water collection and treatment facilities which subsequently discharge into surface water”.*

This definition could have important repercussions for the correct interpretation of the principle of “recovery of the costs of the water services” mentioned in article 9 of the WFD.

Article 4 expounds the environmental objectives of the WFD. Paragraph b) establishes the objective of “protecting, enhancing and restoring all bodies of surface water, subject to the application of subparagraph (iii) for artificial and heavily modified bodies of water, with the aim of achieving good surface water status at the latest 15 years after the date of entry into force of this Directive”

The increase in water demand in recent decades has led to a reduction in river flows and a decrease in the level of groundwater. Both factors involve a loss of quality water which is incompatible with the stated environmental objectives of the EU. For instance, in Spain where 28% of the water abstracted for irrigation is groundwater, there are 51 hydrological units with problems of overexploitation which totalled 710.7 Hm^3/year (Libro Blanco de las Aguas Subterráneas, 1995).

Article 9 WFD says that:

> *“Member States shall take account of the principle of recovery of the costs of water services, including environmental and resource costs, having regard to the economic analysis conducted according to Annex III, and in accordance in particular with the polluter pays principle.”*

Estimating costs is important an important of several aspects of the economic analysis, and the WATECO Guide (2003) summarises this aspect as follows:

- Assessing whether the principle of **recovery of the costs** of water services is met
- Conducting a **cost-effectiveness analysis** of alternative policy measures or projects
- Assessing the costs of alternative options in the **designation of heavily modified water**
- Assessing the need for a derogation based on an economic appraisal of disproportionate costs (such as for the setting of **less stringent objectives or a time derogation**).

Note that the Directive defines costs as *economic costs*, which are the costs to society as a whole, as opposed to *financial costs*, which are the costs to particular economic agents.

In general terms, according to the Wateco Guide, at present the highest priority should be given to developing the following aspects of the economic topics:

- General framework for undertaking economic analysis at basin or sub-basin level
- List of economic and environmental indicators and approach to make them operational
- Specific methods for assessing financial cost and across-sector subsidies and multiple functional infrastructure cost sharing.
- Specific methods for assessing environmental and resource cost
- Practical examples and illustration
- Governance and participatory conflict resolution approaches.

8. CONCLUSIONS

This chapter has introduced the relationships between WFD and agricultural economics, as a good example of the increasing influence of environmental norms in all industrial sectors and generally speaking in all dimensions of economic activity.

The review of WFD shows the urgent need for applied economic analysis and some of the knowledge is required in the field of decision models, and indicators integration. This is the field where the present book tries to make a contribution.

9. ANNEX: MAIN NORMS PRECEDING WFD

The legal acts.

In the following section the most relevant directives that are part of EU Water policy are described in more detail. These directives have a direct influence on water management and have influence on agricultural water use.

Council Directive 76/464/EEC of 4 May 1976 on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community. Amended by: Council Directive 90/656/EEC of 4 December 1990; Council Directive 91/692/EEC of 23 December 1991.

This directive intends to reduce emissions of certain substances discharged by industry to the aquatic environment. These substances have in common that they are toxic, persistent and bio-accumulated.

This Framework Directive leaves it to the discretion of the Member States either to choose Emissions Limit Values or to lay down Environmental Quality Standards to reach this aim. Besides the United Kingdom all Member States have chosen the Emission Limit Value's approach. Emission Limit Values should have been agreed for every single substance, our of a list of 129-among those some substances used as pesticides. Until the year 2000 Emission Limit Values have been laid down for only 18 substances. Although they had to develop 129 Emission Limit Values, Member States and EU-Commission did not succeed in complying with the demands of this Directive to set out more Emission Limit Values.

The new Water Framework Directive incorporates in its article 16 the aim to reduce the emission of dangerous substances into the aquatic environment. In this context a new procedure (COMMPS-combined monitoring-based and modelling-based priority setting) was developed to identify relevant substances (Commission 2000). After identification a risk assessment is applied to suggest a reasonable limit value. A decision establishing the list of substances is under preparation (Decision 2000). A list of 32 "priority substances" for early regulation has been proposed in January 2001 (Communities 2001).

Council Directive 91/271/EEC of 21 May 1991 concerning urban waste water treatment.

In the 1980ies excessive eutrophication caused undesirable ecological changes and harmful algae blooms in inland water bodies and coastal zones. They also have adverse public health implications. Urban Waste Water Directive was an important contribution for the amelioration of the water quality in rivers and on the shore of European Union (EEA 1995).

The Urban Waste Water Directive (Directive 1991) aims to contribute to reduction of pollution by urban sources. The Directive lays down basic Emissions Limit Values for urban waste water treatment plants. It defines, according to a precise timetable, the steps in which the facilities for the treatment of captured sewage have to be applied in all Member States until 2005. Member States can determine in their own responsibility "sensitive areas" (Map 1) with the option to establish treatment facilities for a more efficient degradation of nutrients. I those "sensitive areas", waste water treatment facilities have to include some special treatment to reduce the content of phosphorous and nitrogen. In some Member States (e.g. Germany that identified large parts of the North Sea and Baltic Sea catchments as sensitive areas) this Directive provoked high additional costs for the consumer. In other Member States (e.g. Portugal, that only identified hot spots as sensitive and most of the West Coast as less sensitive areas) important investments covered by EU Structural Funds were realised (Commission 1999). Besides the rejects from urban waste water facilities, agricultural use of fertiliser represents an important diffuse source for nutrients.

Council Directive 91/676/EEC December 12 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources.

High nitrate leakage from mainly diffuse agricultural sources led to contamination of wide ranges of groundwater resources (EEA 1995). Main sources of these nutrients are fertilisers intensely used, and often applied in too high concentrations, in agriculture. The Nitrate Directive intends to tackle these diffuse agricultural sources of nitrates by regulating the use of natural manure. To comply with this task Member States have to define "good agricultural practice" including the use of fertiliser. Further they have to identify vulnerable zones (see Map 2).

In 1997 EU-Commission stated that in most Member States this Directive has not been properly implemented, hence 13 Member States were brought to court (Commission 1997). The reduction of the diffuse nitrate emissions coming from agricultural sources (fertilizer and livestock manure) is relevant for water quality in lakes. Examples prove that specific requirements of the end-user on the quality of agricultural products- including special production techniques in regard to fertiliser –can influence agricultural practices and help to reduce pollution. Products from so called "ecofarming" are supposed to leak less nutrients to groundwater. Further, water suppliers of urban areas can have influence on the production techniques applied in the catchment of their wells.

Council Directive 96/61/EC September 24 1996 concerning integrated pollution prevention and control.

Directive 96/61/EEC concerning integrated pollution prevention and control, requires Members States to have a system for issuing operating permits for certain types of industrial installations based on Best Available Techniques (BAT) as defined by the Directive. Small installations however are not covered by IPPC. EU-Commission expressed the intention to include the requirements of the IPPC-Directive into the Water Framework Directive in the sense that BAT would be applicable at least for those small installations emitting into waters.

The implementation of the IPPC-Directive into the Water Framework Directive in the sense that BAT would be applicable at least for those small installations emitting into waters. The implementation of the IPPC-Directive is still on-going (UBA 2000), (EIPPCB 2000). It is supposed to influence industrial production and reduce resulting pollution to all media, i.e. air, soil and water.

Council Directive 98/83/EC November 3 1998 on the quality of water intended for human consumption.

The Drinking Water Directive was first agreed in 1980 and revised in 1998. It currently contains 48 parameters defining the quality of drinking water for human consumption. Limit values for pesticides and nitrates had an influence on agricultural policy. Limit values for asbestos and lead have an impact on the installations. Although the drinking the drinking water directive aims to protect the end-user, its limit values are important for the quality of resource, its protection and the purification of the water abstracted from the resource. Even the Pesticides marketing Directive makes direct reference to the respective limit value in the Drinking Water Directive.

The Directives described above have been identified as elements of European Water Policy that have major influence on water use in agricultural irrigation. From these descriptions it may already become clear that water policy is severely influenced by activities which fall under different European Policies.

Although an overall concept for European Water Policy was missing, the water directives aimed all towards the same environmental objective: to assure in all Member States a high level environmental quality (EC Treaty Art. 174). Nevertheless a commonly agreed aim for the quality of waters in European Union was lacking. Therefore, for every legal act the precise quality level to be achieved had to be negotiated between the Member States. Only specific sources of pollution were concerned by the legislation. Therefore, the task to fulfil the requirements of the directives i.e., assure a certain level of water quality, laid only in the hands of a well defined type of actor: farmers, certain industries and communes.

With the development of an integrated approach for the protection of the environment, other policies became more concerned with the requirements of the Water Policy. With the development of the reference documents on the best available techniques (BAT) foreseen in the IPPC Directive an important process started, leading to the review of industrial processes responsible for environmental pollution. New measures regarding the protection of the environment were adopted in the reform of the CAP proposed in the Agenda 2000.

4.

WADI scenario definition

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1. Introduction

This document is based upon deliverable D5 of the WADI project. The document considers possible future scenarios for both EU-15 agricultural and water policy. It provides an integration of agricultural and water policy scenarios from a qualitative perspective. Finally, it deals with definition of these scenarios for agriculture in Europe for the purpose of modeling the impact of policy change on the irrigation sector, first, presenting the key assumptions and narratives that describe the various future scenarios and, second, providing estimates for values of key input parameters to be used in modeling of future scenarios for the WADI project.

2. WADI Scenario Methodology

This section defines the purpose of scenarios as a basis for exploring the implications of possible futures.

2.1. Approach

Scenarios are statements about possible futures. They are not predictions about what will happen. They are statements of what is possible; of prospective rather than predictive futures;

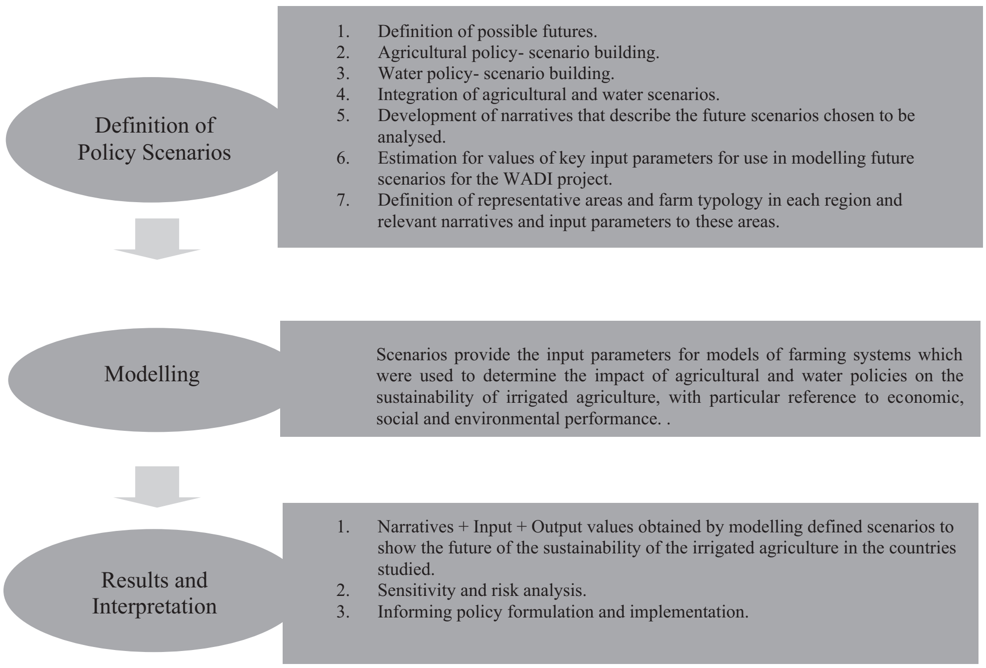
propositions of what could be. Scenarios are not intended to predict the future (DTI, 2002). Rather, they are tools for thinking about the future, assuming that:

- The future is unlike the past, and is shaped by human choice and action.
- The future cannot be foreseen, but exploring the future can inform present decisions.
- There are many possible futures: scenarios map 'possibility space'.
- Scenario development involves a mix of rational analysis and subjective judgement.

Figure 4.1 shows the different phases for the WADI scenario building process. External and internal drivers both for agricultural and water policy are defined in this document. As a result, scenarios for European agricultural policy and water policy are defined separately, and then in combination.

The data and information derived provide inputs to model the impact of policy change on the characteristics and performance of the irrigation sector. A set of key indicators are used to interpret the output of the modelling process and to assess the performance of irrigation in terms of economic, social and environmental criteria. The overall purpose of the analysis is to inform policy design and implementation.

Figure 4.1. The WADI scenario building process as a part of the total project



WADI scenarios aim to inform and advise a range of decision makers such as irrigators, scientists and policy makers.

2.2. Generic scenarios

The construction of the future agricultural and water scenarios for WADI Project builds on a global and national review of futures scenarios constructed by the UK Foresight Futures programme (Berkhout et al., DTI: 1999, 2002). The Foresight Programme identified 5 main dimensions of change:

(a) Demography and settlement patterns

(b) The composition and rate of economic growth

(c) The rate and direction of technology change

(d) Social and political values

(e) The nature of governance

The Foresight Futures framework focuses primarily on the last two dimensions when applying exploratory scenarios. This is judged sufficient when the sectors under study are located in developed countries. In developed nations human demography is relatively well characterised in current population models and hence there would be little to gain from scenario elaboration. According to the Foresight Futures framework economic growth can be regarded as the outcome of a set of institutional factors (fiscal and monetary policies, trade liberalisation, regulation and legislation) rather than an autonomous driver of change. Likewise, perhaps more controversially, the rate and direction of technological change is regarded as being shaped by market, regulatory, political and cultural factors and is not regarded as an exogenous factor of change.

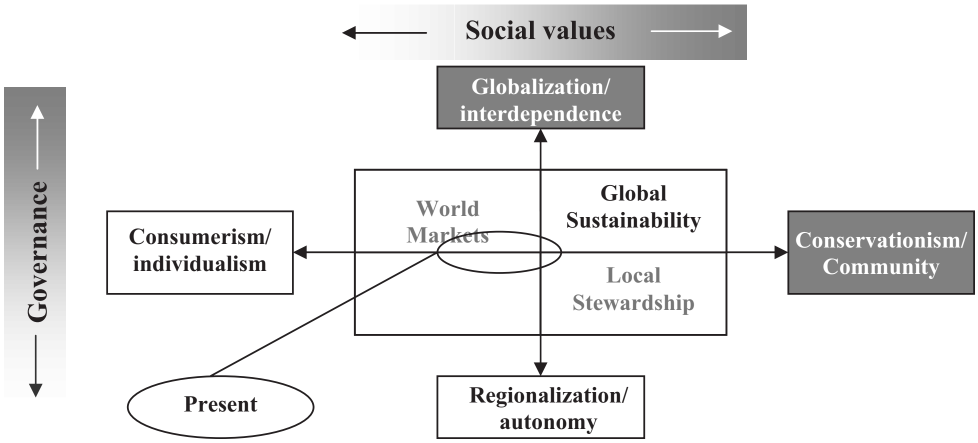
On this basis, four possible futures were constructed which are distinguished in terms of two dimensions of change: **social values** and **governance**.

The **social values** dimension accounts for policy making priorities and patterns of economic activity, including consumption behaviour. At one end of the axis denoted by *consumerism/individualism*, values are dominated by private consumption, personal freedoms and short term considerations. Here, markets and economic factors are the major determinants of resource use and human activity. At the other end denoted by *conservationism/community*, there is a greater concern with collective interest, social cohesion, equality, and long term goals such as sustainable development.

The **governance** dimension represents the structure of political authority and decision making. At one end denoted by *globalisation/interdependence*, governance is increasingly distributed away from the national level towards country groupings or international organisations, such as EU or WTO. In such situations the importance of international boundaries reduce, and economic, social and political agendas are increasingly set above the level of any individual nation or region. At the other end denoted by *regionalisation/autonomy*, decision making is retained at national and increasingly regional levels. Sovereignty is retained over key areas of policy: the process of globalisation is weakened. Regional government has greater autonomy over decision making, and economic, social and political boundaries are strengthened. National and regional development reflects local capabilities and resources.

The four scenarios are illustrated in figure 4.2. They can be described by narratives or story-lines and selected indicators. The current dominant development paradigm is shown to be mainly a mix of World Markets and Provincial Enterprise.

Figure 4.2. Possible Futures, based on Foresight (DTI, 1999)



World Markets are characterised by an emphasis on private consumption and a highly developed and integrated world trading system.

Global Sustainability: is characterised by more pronounced social and ecological values, which are evident in global institutions and trading systems. There is collective action to address social and environmental issues. Growth is slower but more equitably distributed compared to the World Markets scenario.

Provincial Enterprise is characterised by emphasis on private consumption but with decisions made at national and regional level to reflect local priorities and interests. Although market values dominate, this is within national/regional boundaries.

Local Stewardship is characterised by strong local or regional governments which emphasise social values, encouraging self-reliance, self sufficiency and conservation of natural resources and the environment.

This scenario framework can be adapted to provide an analytical framework within which to explore European agricultural and water policy options as they affect irrigation.

3. AGRICULTURAL POLICY – SCENARIO BUILDING

Drawing on the aforementioned framework, a number of Agricultural Policy Scenarios are constructed which reflect variations in the type and extent of support to the farming sector. Particular reference is made to Agenda 2000 Reform of the Common Agricultural Policy (CAP), the CAP mid-term review proposals and future prospects for agricultural commodity markets, including those for irrigated crops.

The WADI project focuses on changes in EU-15 agricultural policy as they affect the economic, social and environmental performance of irrigation in the partner countries. Table 4.1 links the Foresight Scenarios with scenarios for agricultural policy, together with a brief description of the agricultural policy regime. The **Baseline** is taken as the agricultural policy regime in place in 2000/1, as determined by CAP at that time. This 2000/1 baseline is used to provide a relative reference point for the definition of future scenarios. The Baseline is also be extrapolated to 2010 based on predictions (rather than possibilities) of agricultural markets and prices from EU, OCDE and other sources. This extrapolation is referred to as the

Business As Usual (BAU) case. Provincial Agricultural Markets are characterized by projectionist regimes similar to that under pre-reform CAP. Local Community Agriculture, as the label implies, emphasizes sustainability at a local level.

Table 4.1. Links Between Foresight and Agricultural Policy Scenarios

'Foresight' Scenario	Agricultural Policy Scenario	Intervention regime
	Baseline	Moderate: Existing price support, export subsidies, with selected agri-environment schemes
World Markets	World Agricultural Markets (without CAP)	Zero: Free trade: no intervention
Global sustainability	Global Sustainable Agriculture (Reformed CAP)	Low: Market orientation with targeted sustainability 'compliance' requirements and programmes
Provincial enterprise	Provincial Agricultural Markets (Similar to pre-reform CAP)	Moderate to High: price support and protection to serve national and local priorities for self sufficiency, limited environmental concern.
Local Stewardship	Local Community Agriculture	High: Locally defined support schemes reflecting local priorities for food production, incomes and environment

4. WATER POLICY – SCENARIO BUILDING

The scenario approach is also used to classify possible futures with respect to water policy. The implications of possible future water policies can then be interpreted for irrigation, both in terms of how policy influences the scale and characteristics of irrigation, and vice versa. The analysis is predicated on the assumption that changes in irrigation practices have the potential to contribute to sustainable water resource management.

Water policy scenarios have been constructed to fit with the broad framework of the Foresight Scenario referred to earlier in that water policy reflects a mix of governance and social preference. Water policy scenarios are further described in terms of the combination of policy instruments used (e.g. full cost recovery), policy style (e.g. the degree of consensus) and configuration of actors (e.g. active involvement of stakeholders).

Four scenarios are proposed which reflect increasing degrees of commitment to sustainable water resource management namely:

- Unrestricted Water Markets;
- Existing Water Policy;
- WFD Application; and
- Beyond WFD.

Once again these are viewed as possible rather than probable futures.

Table 4.2 summarises the intervention regimes associated with these four scenarios. They are generally consistent with the four Foresight Scenarios presented earlier. In its extreme form, World Markets, characterised by market led resource allocation and highly developed trading systems, would be associated with unrestricted abstraction and use of water driven by economic imperatives. The protection of water quantity and quality would be induced by economic factors and the individual self-interest of water users. The adoption of WFD demonstrates a commitment to sustainability and is associated with a moderation of market processes in favour of resource and environmental conservation. Hence its association with

Global Sustainability. A very strong commitment to water resource sustainability is probably closely linked to the Local Stewardship Foresight Scenario.

Table 4.2. Links between Foresight and Water Policy Scenarios

Linked 'Foresight' Scenario	Water Policy Scenario	Intervention regime
World Markets	Unrestricted Water Markets	Zero: market drivers for water abstraction, use, and environment protection, if any
Provincial Enterprise	Existing Water Policy (Baseline, pre-WFD)	Low: Existing water price regimes, including subsidies, with limited environmental controls.
Global Sustainability	WFD Application	Medium: Targeted national programmes, environmental targets, cost recovery price.
Local Stewardship	Beyond WFD	High: Locally defined support schemes, strict application of protection measures (input use, etc.)

5. INTEGRATION OF AGRICULTURAL AND WATER POLICY SCENARIOS

The preceding sections identified four agricultural and four water policy scenarios. These could offer 16 possible combinations. The broad logic of the Foresight Scenarios suggests that there is likely to be convergence of agricultural and water policy within given scenarios. For example, a reformed CAP which places more emphasis on environmental protection and wise use of natural resources is compatible with the adoption of WFD. Local Community Agriculture, with emphasis on local priorities might adopt sustainable water management 'beyond WFD'. World Markets would imply free trade in agricultural commodities and the establishment of water markets where water is put to its most profitable use, with the risk of negative social and environmental consequences.

It is likely, therefore, but not necessary, that particular combinations of agricultural and water policy scenarios are more compatible than others. For this reason, figure 4.3 identifies four scenario combinations for modelling the possible impacts of policy change on the irrigation sector in the first instance. Sensitivity analysis will suggest whether further combinations are worthy of investigation.

Figure 4.3. Possible Integrated Scenarios for WADI Project

		WADI Agricultural Policy Scenarios			
		Provincial Agriculture (pre-reform CAP)	Global Sustainable Agriculture (Reformed CAP)	Local Community Agriculture	World Agricultural Markets
WADI Water Policy Scenarios	Existing Water Policy (pre-WFD)				
	WFD Application				
	Beyond WFD				
	Unrestricted Water Markets				

6. ESTIMATING INPUT DATA FOR SCENARIO ANALYSIS

6.1. Information sources

Data are needed to describe each agricultural and water policy scenario. These data are used as inputs to the modelling process in order to determine the impact of policy change.

For the purpose of scenario analysis in the WADI project, narratives and quantitative indicator values have been compiled for each scenario. The quantitative estimates are used as input values in the modelling of irrigation systems under policy change. Information for narratives and estimates for quantitative indicators have been drawn from numerous sources, and can be seen in the Wadi D5 document in detail.

Drawing on the estimates contained in this document, table 4.3 summarises selected features of the agricultural scenarios for 2010 in terms of indicators expressed as an index of the existing 2002 situation, where the latter is equal to 100. Table 4.4 contains estimates for 2020.

Table 4.3. Estimated Indices for Selected Indicators for Modelling Agricultural Scenarios in 2010 (2001/2 = 100)

	World Agricultural Markets	Global Sustainable Agriculture	Provincial Agriculture	Local Community Agriculture
Output prices				
Cereals	80-90	90-100	100-110	110-120
Area payments*	0	90-100	95-105	105-115
Vegetables	85-95	110-120	100-110	120-130
Fruits	85-95	95-105	100-110	120-130
Livestock: Meat	85-95	90-100	95-110	110-120
Dairy: milk	85-95	90-100	100-110	115-125
Agric environmental payments	55-60	95-105	40-50	115-125
Input prices				
Fertiliser and pesticides	85-110	130-150	105-115	130-170
Water	115-130	130-150	105-120	140-160
Water infrastructure	130-140	120-130	105-120	110-120
Crop Yields	120-130	110-115	100-110	80-100

Values are likely to fall within ranges shown according to local conditions. See WADI D5

* these payments may be delivered through different mechanisms according to scenario and member state preference, with varying degree of decoupling from direct production support.

The difference between the two time frames reflects the ‘depth of application’ of a particular scenario pathway over time. The longer is the time horizon, the greater is the expected variance between scenarios that is evident in changes in infrastructure, investment, societal behaviour, and the commitment to and impact of particular policy interventions. Climate change, which is likely to have some incremental effects post-2025, has not explicitly been considered in these scenarios.

Table 4.4. Estimated Indices for Selected Indicators for Modelling Agricultural Scenarios in 2020 (2001/2 = 100)

	World Agricultural Markets	Global Sustainable Agriculture	Provincial Agriculture	Local Community Agriculture
Output prices				
Cereals	55-65	75-85	100-110	125-135
Area payments	0	80-90	95-105	100-110
Vegetables	65-75	120-130	110-120	155-170
Fruits	65-75	95-105	115-125	160-180
Livestock: Meat	85-95	90-100	100-110	110-120
Dairy: milk	65-75	85-95	105-115	130-140
Agric environmental payments	50-55	110-120	40-50	135-150
Input prices				
Fertiliser and pesticides	70-85	185-200	105-125	220-270
Water	180-190	150-160	120-140	200-220
Water infrastructure	180-190	145-160	180-190	135-150
Crop Yields	150-170	125-140	120-130	90-100

Values are likely to fall within ranges shown according to local conditions. See WADI D5

6.2. Interpretation and use of estimates

The estimates in tables 4.3 and 4.4 and supporting Appendix 4 were used for modelling the impact of policy change. A number of points were considered by research partners when applying them to their country and region situations:

- The estimates are in constant 2001/2002 prices, expressed as a percentage of existing observed values. The estimates are given as ranges: the mid points were used or some value within the range according to local circumstances, with sensitivity analysis for variations in the estimates.
- The scenarios are broad pictures which were interpreted and modified for the purpose of country and regional circumstances. The possible outcomes of the global markets and global sustainability futures depend on the degree to which local farming systems are sensitive to international markets for agricultural commodities.
- Locally defined scenarios (provincial agriculture and local community agriculture) were mapped out according to local circumstances and preferences within the broad framework provided here. This was particularly the case for regionally specialist production such as vines, olives, fruits, tobacco and cotton, and for particular features of the local agricultural economy and farming systems, such as dominant farm sizes or tenure systems.
- WADI focuses on agricultural and water policy change. These aspects were developed in the scenario analysis to reflect country/regional circumstances. For example, in some situations, existing water pricing regimes involved large subsidies, in others this was be the case. A switch to full cost recovery in situations where there is high current subsidy necessarily involves a larger relative increase in water price compared to situations where current subsidy levels are low.
- The estimates given here are suggestions. They were scrutinised to ensure consistency when applied to a particular case. Scenario analysis rests on the differences between scenarios. It is important that these relative positions are clear and consistent.

Refinement was necessary to ensure this is the case. Furthermore, and particularly important, the scenarios need to be internally consistent, for example with respect to the relative attractiveness of alternative irrigated crops within any one scenario. This was done by scrutinising the crop budgets and irrigation costs generated by each scenario.

- The difference between 2010 and 2020 shows the 'depth of application' of the particular scenario, allowing for a longer time period of implementation and adjustment. It could be that the 2020 futures could apply sooner. The impact of this can be tested in sensitivity analysis.

The future scenarios can be compared with the forecast of agricultural commodity markets and prices for locally relevant commodities which have been produced and are available up to 2012 from EU, OECD, FAPRI. In cases where there is likely to be a mismatch of demand and supply, there may be a need to adjust commodity prices up or down accordingly. Under some scenarios, this balance may be achieved by production quota.

7. CONCLUDING REMARKS

The Scenarios described here are used to explore the impact of changes in agricultural and water policies on the irrigation sectors in selected European countries. In general terms, the CAP reform process and the implementation of the WFD demonstrate a move towards Global Sustainability. However, other futures are possible which vary in terms of social values and governance. The scenario approach provides an analytical framework to describe and quantify likely futures which can be combined with the modelling of dominant irrigation systems in order to support policy management.

5.

A methodology for the analysis of irrigated farming in Europe

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Guido Maria Bazzani wrote sections 3.2, 3.3, 4.1 and 4.2; Davide Viaggi wrote sections 2.2 and 3.1; J.Berbel Vecino, M.J. López Baldovín and C. Gutiérrez Martín wrote section 4.3. Sections 1 and 5 were written jointly by the team of authors.

1. Introduction

The general objective of WADI is to analyse the sustainability of irrigated agriculture in Europe within the context of the post-Agenda 2000 CAP Reform and of the Water Framework Directive.

To be more precise, the project aims to analyse the role of irrigated agriculture in Europe, and in doing so, to try and answer the following three questions:

- What contribution is made to the reaching of CAP and EU-15 objectives?
- What contribution to rural development does it make?
- What contribution is made to sustainable development and biodiversity?

In order to achieve such ambitious goals, an integrated approach, sub-divided into three main phases, has been adopted: this approach aims to:

1. forecast scenarios for the future of irrigated agriculture in Europe.
2. integrate the OCDE sustainability indicators into a general model for irrigated agriculture.
3. build simple operative models consisting of different techniques for the assessment of the multifunctional impact of the forecasted scenario on irrigated agriculture.

It should be noted that while phases 1 and 2 are mainly qualitative, phase 3 requires a strictly quantitative approach.

2. QUALITATIVE ANALYSIS

The first part of the methodology combines phases 1 and 2, and requires a complex approach based on different qualitative analyses as briefly summarized in the following scheme:

PART I: QUALITATIVE ANALYSIS
A) Set up the WATER POLICY scenario framework:
A1) The technology and physical structure of irrigation
A2) Institutions at the national level: prices of water, laws and companies
A4) Selection of a set of indicators according OCDE guidelines
B) Set up the POST AGENDA 2000 scenarios
B1) The impact of Agenda 2000 on irrigated agriculture
B2) The global evolution of agriculture
C) Combine both analyses and produce long-term scenarios
C1) The definition of the scenarios

2.1. The definition of scenarios

Within this context, the term "scenario" means a statement about a possible future. Such scenarios are not predictions about what will happen, but are statements about what may happen. The scenarios arise as a consequence of the drivers of economic and social change, new ideas, fashions, scientific discovery, technology development and innovation, purposeful policy interventions, and of unexpected events which can have a major impact.

The scenarios suggest *possible* futures, exploring alternative directions in which social, economic and technological changes may evolve over coming decades. The definition of a scenario integrated a complete set of studies mainly based on the existing literature concerning:

- An analysis of the technology and physical structure of irrigation in Europe.

Laws and Institutions at the national level of analysis: water's legal status, prices of water, water markets, water suppliers and institutions, the structure of investment funding, etc

- An analysis of European water policy focusing on water use for irrigation.

Information regarding scenarios narratives and estimates of quantitative indicators have been drawn from numerous sources, based on previous studies, including the following:

- Foresight (DTI, 1998) and UK Climate Change Impact Study (UKCIP, 2001);

- Statements on global food and water futures (EU, OECD, FAPRI, Rosegrant et al, 2001; 2002);
- Assessments of scenario analysis made under previous and ongoing EU funded land use change and climate change research projects, notably REGIS, ACCELERATE, ATEAM and MULINO). The ACCELERATE programme in particular has recently developed agricultural scenarios through a consensus based approach conducted amongst its partner organizations (see www.cordis.lu for additional information).
- The framework for scenario analysis and state-of-the-art about water and CAP policies has been published as a CD-ROM (see www.uco.es/grupos/wadi for additional information) distribution of which began at the European Conference of Agricultural Economics (Zaragoza, 28th August 2002)

Forecasted scenarios for the future of European Irrigated Agriculture have shifted from the status quo represented by Agenda 2000, as we explain in previous chapter there are four scenarios can be briefly summarized as follows: *World Markets; Global Sustainability; Provincial Enterprise; and Local Stewardshi*p. For each of these four general scenarios, water and CAP scenarios are then defined as table 4.2 summaries in previous chapter. The reference time horizon was set at 2010 for all scenarios.

Beyond the initial stage, where scenarios consist mainly in a 'storyline', quantitative indicators illustrating the direction and rate of changes in the respective parameter to be used during the simulation phase were estimated. The quantification of these coefficients takes into account a combination of Agricultural and Water Policies Scenarios corresponding to the national and local specificity of the study. In particular, an estimation has been made of the indicators of the *impact on irrigated agriculture*, such as: farming systems affected by the reform, the impact on irrigated crops' profitability, changes in crop areas, the evolution of employment generation, water consumption, fertilizer and pesticide use, etc.

2.2. Indicators

The task at hand concerns the identification of suitable indicators for a multidimensional evaluation of the impact of irrigated agriculture on the economic, social and environmental aspects of sustainability.

In particular, the aim is to select a limited number of parameters that can be fed into the mathematical models that will be developed during the quantitative phase in order to evaluate the impact on irrigated agriculture according to different policy scenarios.

On the basis of existing studies – paying special attention to the OCDE proposal (York, 1999)- a series of indicators (shown in table 5.1), designed to check and control the sustainability of agriculture at farm level, have been selected.

Indicators express the impact per hectare of usable farmland, thus making them comparable among farms and among different countries.

The most obvious indicators are those pertaining to the consumption of water, the emission of nutrients and the use of pesticides, as they are directly related to the pollution of water resources and appear more directly quantifiable at farm level.

Indicators of the economic viability of farming can also be used to assess the possible effects of water policies on the economic sustainability of agriculture, (that is, on farm income). Moreover, the social aspect of agriculture is revealed in particular by farm employment and other related indicators.

Table 5.1. Selected indicators

Area	Selected indicators
Economic balance	Farm income Farm contribution to GDP Public support
Social impact	Farm employment Seasonality
Landscape and biodiversity	Genetic diversity Soil cover
Water use	Irrigation technology Water use Marginal value of water
Nutrients and pollutants	Nitrogen balance Pesticide risk Energy balance

2.2.1.- *Farm income*

Farm income is defined by the OECD as net farm income calculated as the difference between the value of gross output and all expenses, including depreciation at the farm level from agricultural activities (OECD, 2001, pg. 65). This indicator is one of the key indicators of the sustainability of agricultural systems, and is designed to measure the financial viability of farming. If financial returns are consistently negative, then any farming system will be unsustainable.

This indicator has to be distinguished from household income, which can be supplemented by non-agricultural activities and/or by summing up revenue from different productive factors employed on the farm (labor, capital).

Table 5.2 suggests a way of calculating farm income.

Table 5.2. Farm income calculation

1. Gross output	1.1. Sales of crops and livestock products
	1.2. Direct payments
	1.3. (Other) Receipts from agricultural activities
2. Expenses	2.1. Intermediate consumptions (seeds, services, etc.)
	2.2. Taxes
	2.3. Wages and salaries
	2.4. Rent
	2.5. Interests
	2.6. Depreciations
3. Farm income (1-2)	

In order to understand the sustainability of agriculture in the medium/long-term, net profit has been adopted, by subtracting rent, depreciation and farm household labor.

2.2.2.- *Farm contribution to GDP*

Farm contribution to GDP is not defined as an indicator by the OECD, as it mainly plays the role of contextual information. It has been estimated as the value added produced at farm level i.e. the difference between total revenue and intermediate consumption. Thus it is a measure of the contribution of the farm to economic wealth, and it also takes account of items that are subtracted as costs when we consider farm income only.

2.2.3.- *Farm support*

Farm support is a measure taken into account by the OECD as a contextual indicator provided it is related to agricultural-environmental policies. It measures the net support accorded to agriculture, and is important from two points of view. Firstly, the public decision-maker needs to know the amount of funding to farming and how this funding is going to change over time. Secondly, there is the question of equity, in the degree of support to farming.

2.2.4.- *Farm employment*

Farm employment is defined by the OECD as agriculture's share of total civilian employment (OECD, 2001, pg. 43). The OECD proposes farm employment as a contextual indicator designed to measure the importance of agriculture in providing employment within the context of the national economy. Furthermore, farm employment can provide a measure of the social implications of agriculture in terms of the provision and distribution of income. As such, it is one of the main indicators of the social importance of agriculture. It may be defined as the total amount of labour requested by the farm, and hence a measure of the total employment guaranteed in the farming sector.

2.2.5.- *Seasonality*

A seasonality index quantifies the distribution of labour over the year. It is related to the kind of work needed (e.g. peak periods call for the employment of external, often non-local labour, sometimes poorly qualified).

2.2.6.- *Genetic diversity*

Genetic diversity, as defined by the OECD, is the total number of crop varieties/livestock breeds that have been registered and certified for marketing for the main crop/livestock categories (OECD, 2001, pg. 299). According to the OECD, this indicator represents the simplest form of biodiversity indicator. For our purposes, this indicator has been equated with the number of species of crop/livestock present on the farm.

2.2.7.- *Soil cover*

Soil cover is defined by the OECD as the number of days in a year that the soil (agricultural land) is covered by vegetation (OECD, 2001 pg. 102). This definition is quite straightforward, and is an indicator of the fraction of total time that farmland is covered by crops. This indicator is particularly important in areas where leaving the soil bare may lead to problems of soil erosion. Moreover, coverage means the possibility of maintaining a greater variety of wildlife.

Soil cover (Sc) is calculated as follows:

$$Sc = \frac{\sum_i s_i v_i}{\sum_i s_i}$$

where s_i is the surface of crop i and v_i is the fraction of time during which the crop i covers the soil over the year.

2.2.8.- *Water use*

Water use is defined by the OECD as the share of a nation's total water use represented by agricultural water use (OECD, 2001, pg. 174). For our purposes, water use is intended as the required amount of irrigation water measured at the farm gate (and thus includes all waste and inefficient use on the farm). This is proposed as a "related information" (OECD, 2001, pg. 178). It is proposed in this form by the European Commission for the Evaluation of AEPs, and in this simple form is a clear measure of water use in agriculture.

Water consumption as a function of water price *wp*, given farm production potential and characteristics Q, can be seen as the farm's demand for water:

$$W \neq w(\ p\ ;Q)$$

2.2.9.- *Marginal value of water*

The marginal value of water can be obtained from the demand curve, as a result of the WADI models. It is complementary to the information about water use as it gives a marginal value for water, comparable to price.

2.2.10.- *Irrigation technology*

Irrigation technology is proposed by the OECD as a farm management indicator. It represents a way of evaluating the technological status of irrigation and the changes it undergoes. It is also an approximation of the efficiency of water management and distribution. It is calculated as the total water used by each irrigation technology (flooding, high pressure rain guns, low pressure sprinklers and drip emitters) divided by the total water distributed by all systems. This indicator is relevant provided the models allow for a choice between the various different irrigation technologies.

2.2.11.- *Nitrogen balance*

Nitrogen balance, according to the OECD definition, is the physical difference (surplus/deficit) between nitrogen inputs and outputs from an agricultural system, per hectare of agricultural land (OECD, 2001, pg. 120). This is the main form for calculating the surpluses of nitrogen that are a potential risk for the environment. It could also be considered the main indicator of the impact of farming on the environment as far as groundwater quality is concerned.

All nitrogen put into cultivated soil is considered to be input, while the harvested production is considered as output. The difference is the net amount of nitrogen that, over one year, is released into the environment (air, soil, water). It could be positive, thus indicating a surplus, or negative, thus pointing to a deficit.

The value of nitrogen balance, and of other nutrient and pollutant indicators (I) when required, is calculated as the difference between input and output at the farm gate:

$$I_k = \sum_i \sum_j s_i x_{ij} c_{jk} - \sum_i \sum_z s_i y_{iz} d_{zk}$$

where:

s_i = surface of crop i;

x_{ij} = amount of input j per hectare of crop i;

c_{jk} = amount of indicator k (pollutant/energy) per unit of input j;

y_{iz} = amount of output z produced by crop i;

d_{zk} = amount of indicator k (pollutant/energy) per unit of output z.

2.2.12.- *Pesticides risk indicators*

A pesticides risk indicator, according to the OECD definition, is the trend in pesticide risk over time, estimated by combining information about a pesticide's toxicity and exposure to that pesticide, with information about pesticide use (OECD, 2001, pg. 149). There are many ways of calculating indicators of this kind: three alternatives are proposed by the OECD. Their basic structure is the following:

Pesticide risk = exposure/toxicity*area threatened

where exposure depends on the quantity of pesticide in the water and may be calculated in many different ways, including scoring. Toxicity may be intended as the quantity of pesticide needed to kill 50% of a given population of organisms exposed to the pesticide. The area threatened is the area affected by the presence of the pesticide.

For the purposes of WADI, the value of the index c_{jk} is calculated as follows:

$$c_{jk} = \sum_t a_{jt} \frac{1000000}{DL50_t}$$

where:

aj_t = amount of active matter *t* by unit of input *j*;

$DL50_t$ = lethal dose 50 of the active matter *t*.

The indicator represents the weight (in kilograms) of the population of rats, 50% of which would be killed by 1 kg of the input.

2.2.13.- *Energy*

The energy balance of the farm where crops are rotated may be calculated using the input-output approach. There is no such OCDE standard for agriculture, but a detailed balance scheme has been developed on the basis of the many studies made of this question: it considers all variable inputs containing energy (seeds, fertilisers, etc.).

3. QUANTITATIVE ANALYSIS

The objective of quantitative analysis is to develop mathematical models of representative farms in order to get quantitative knowledge of the multidimensional impacts of irrigated agriculture in the different areas of the EU-15.

Nowadays these irrigated agricultural systems need to be re-evaluated in terms of their sustainability rather than in terms of the old profitability concept, and their multi-functional dimension has to be taken account of. Sustainability can be sub-divided into three main varieties:

- Economic sustainability (farm and rural income).
- Social sustainability (labour and rural development).
- Environmental sustainability (water consumption, fertilisers, pesticides, biodiversity, etc.).

A more detailed analysis was carried out following an integrated path, as shown below:

PART II: QUANTITATIVE ANALYSIS

D) Definition of representative irrigated areas
  D1) Descriptive analysis of irrigated area
  D2) Analysis and definition of representative areas
  D3) Definition of representative farms by selected areas
E) Modeling representative farms
  E1) Definition of mathematical programming techniques
  E2) Short-term (static) analysis
  E3) Long-term (dynamic) analysis
F) Model exploitation and result analysis
  F1) Economic Analysis
  F2) Social analysis
  F3) Environmental analysis

Phases D and E involved the followings steps :

- Identification of the Basins
    - Statistical data analysis (FADN)
    - Homogeneous production district definition
- Data collection - ad hoc survey
    - Cluster analysis
        - Identification of representative farms
            - Farmers' behaviour
            - Crop mix
            - Production/irrigation technologies

            ….
- Modelling
    - Calibration
    - Validation
    - Scenario analysis (what-if)
- Interpretation of results and policy recommendations

3.1. Definition of representative irrigated areas (basins) and farms

The selection of study areas was carried out at the national level, since farming is substantially an activity specific to a given local area. Selection was based on different factors such as: localization, climate, types of soils, available water resources, crops, etc. The definition of different irrigated areas was based on the following criteria: type of cropping pattern, technical characteristics of the systems, management systems, complementary or essential role of irrigation in specific areas. Other criteria were considered, where necessary, on a case-by case approach.

Farm typology was selected on the basis of recent census data, together with interviews with local experts, and ad hoc surveys of farmers from various different water-users associations.

Cluster Analysis was extensively used as an exploratory data analysis tool for solving classification problems. Cases were sorted into groups, or clusters, and the degree of association is strong between members of the same cluster and weak between members of different clusters. Such techniques may be hierarchical or non-hierarchical: the k-means method, i.e. non-hierarchical clustering, was generally adopted here.

3.2. Modelling representative farms

The methodology adopted is based on mathematical models coupled with agri-environmental indicators.

Simulation models based on mathematical programming techniques are widely used in agriculture (Hazell & Norton, 1986), and there is a large body of work focusing on irrigation problems.

Such studies reveal that multi-criteria analysis seems able to provide a better interpretation than the simple profit-maximizing approach (Romero and Rehman, 1989; 1993; Berbel and Rodriguez, 1998; Gomez-Limon and Arriaza, 2000).

In WADI, this latter approach is adopted by applying the Multi-Attribute Utility Theory (MAUT) paradigm, which is closely linked to a multi-criterial problem (Ballestero and Romero, 1998). The utility function is assumed to be linear, thus combining the easy handling of the model and a reasonable degree of reliability of the results. MAUT takes the following general form:

$$U_f = \sum_{j=1}^{n} w_j r_{fj}$$

where: U_f is the utility value of farmer f; the index j identifies attributes; w_j is attribute weight; r_{ij} is the normalized value of the attribute.

The aggregate utility function requires normalization since different units are involved, and it can be quantified as:

$$U = \sum_{o} w_o * \frac{Z_o^+ - Z_o}{Z_o^+ - Z_o^-}$$

where: U represents the utility index; Z, Z^+, Z^- are objectives values, ideal and nadir (*ideal* and *nadir* are respectively the best and worst case), w represents weights.

The adopted approach is based upon a descriptive model of farmers' behavior - one as close as possible to reality, and therefore inclusive of various objectives taken into consideration in the decision-making process. Evidence suggests that these objectives are those of profit, risk, management difficulties, etc.

The relevant criteria are selected according to the empirical evidence within each area.

Income is defined according to the time horizon considered.

The risk attribute can be specified in different ways, including the quadratic E/V and the linear MOTAD, maximum or total negative semivariance approach.

No problem is raised by labor minimization, since the attribute always explicitly enters the model as a coefficient.

Other attributes, such as a management complexity, require an ad hoc index. The attribute weights are quantified in a non-interactive way according to a methodology, proposed by Amador *et al* (1998) and adapted by Berbel & Rodriguez (1998), based on the minimization of the distance of model results from actual farmers' choices via goal programming.

3.3. The economic model of water demand

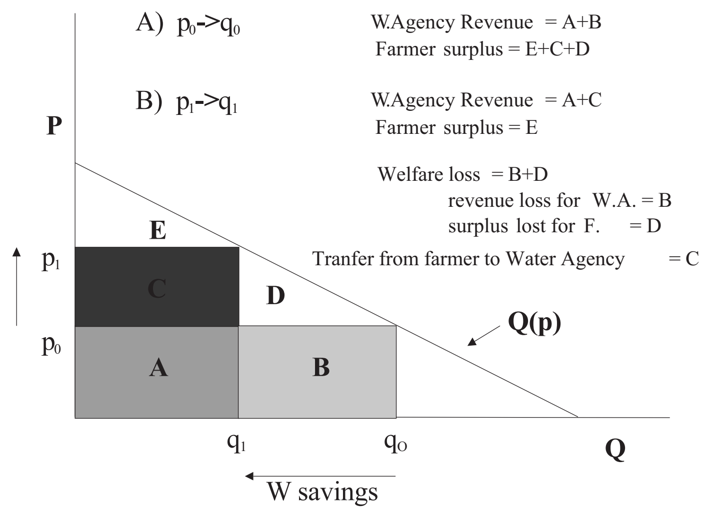
The quantity of water demanded by farmers in a given district during a certain period *q* is an inverse function of its price *p*. Such a function q=Q(p), where *p* is water price and *q* is water consumption measured as the volume of water consumed per unit of surface, is called *water demand* (figure 5.1). This relation, which enables us to identify water consumption at a given price, constitutes a precondition for defining water policy.

To see how the model works, we can apply it to a simplified economy with only two agents: a water consumer, i.e. a typical farmer, and a Water Agency (WA).

From the farmer's point of view, water is a production factor which may lead to higher returns, and expand the range of available options, i.e. the cultivation of more profitable crops, and increasing quality and/or production levels of the existing ones. In general, crop response to water is not linear; in fact, beyond a certain level of irrigation, resource productivity follows a decreasing pattern. So at farm level, the economic benefits from water vary not only among crops but also according to irrigation levels. A general assumption is that farmers have all the necessary technical and economic information they require, and act as profit maximizers. Consequently, farmers irrigate until benefits rise above costs.

The marginal benefit of an additional dose guides the farmer in water allocation. The value of such benefits determines the farmer's marginal willingness and ability to pay, and this explains the fall in the demand curve in figure 5.1. The area below the curve represents the farmer's total benefit when water is a free good; this area represents *consumer surplus* (*CS*).

Figure 5.2 - Water demand function



Imposing a price on the resource means an additional cost for users and revenue for the Water Agency (*WAR*). If the price were p_0, the quantity demanded would be q_0 and revenue $WAR = p_0 q_0$, graphically A+B; the benefit perceived and still not paid by the user *CS* becomes the triangular area ECD.

Price determines a twofold effect: on the one hand, it reduces water consumption, in other words it enables water to be saved (WS), while on the other hand, it reduces farmer surplus (CS).

Since these effects are crucial to the definition of water policy, they deserve closer attention. Another important piece of information can be derived from this function: i.e. the reactivity of demand to price. The elasticity index ε is the ratio of two relative variations - in quantity and price respectively - and can be expressed as

$$\varepsilon = \frac{\Delta Q / Q}{\Delta P / P} = \frac{\Delta Q}{\Delta P}\frac{P}{Q} \text{ or as } \frac{dQ}{dP}\frac{P}{Q}.$$

Assuming a change in price from p_0 to p_1, we can easily estimate the level of water saved $WS(p) = q_1 - q_0$ simply by applying the elasticity formula $WS(p) = Q_0\ \varepsilon\ \Delta P$.

The Water Agency revenue moves from A+B to A+C, while consumer surplus decreases to E.

The increase in price determines a welfare loss WL identified by the area under the water demand curve in figure 1 expressed as: $WL(p) = \int_{p_0}^{p_1} Q(p)\delta p - Q(p)\,p$.

WL is formed by two separate components: a welfare loss experienced by farmers (represented by the area D), a Water Agency revenue loss (area B); the area C represents not a loss but a welfare transfer from farmers to the Agency.

In order to derive the water demand function, mathematical programming is used and in general the farmer's problem is cast as a constraint maximization and in the simpler case can be formalized as:

$$\max_{\{X,W\}} \text{INC} = \sum_c \sum_i \sum_s \left\{ X_{c,i,s} \left[p_{c,i}\, q_{c,i,s}\left(wr_{c,i,s}\right) + su_c - vc_{c,i,s} \right] \right\} - \sum_k \sum_l \sum_p W_{k,l,p}\, wp_{k,l,p} \qquad (1)$$

subject to:

…

$$\sum_s \sum_c \sum_i X_{c,i,s}\, ir_{c,i,s} \le \sum_l W_{k,l,p} \quad \forall k, p \qquad (2)$$

…

where the indexes represent: *c* crop, *i* irrigation level, *s* type of soil, *k* water source, *l* water provision level, *p* period. To distinguish between variables (endogenously determined) and parameters (exogenously fixed), the former are written in capital letters: *INC* income (€), $X_{c,i,s}$ activities[3] (ha), $p_{c,i}$ crop market price (€/t), $q_{c,i,s}\ (wr_{c,i,s})$ crop production as function of water, $wr_{c,i,s}$ crop water requirements, su_c subsidies (€),$vc_{c,i,s}$ variable costs (€), $W_{k,l,p}$ water demand

[3] An activity is a crop characterized by its production process, i.e. fertilization, irrigation, etc.; the same crop determines distinct activities if more production possibilities are considered.

(m^3), $wp_{k,l,p}$ water price (€/m^3),[4] ha_s available surface (ha), $ir_{c,i,s}$ crop irrigation requirements (m^3).

It should be pointed out that in equation 1, representing the farmers' objective function, production q is expressed as a function of water and irrigation costs are kept separate. This approach enables us to derive the *water demand function* (3) (from equation 1) quantifying the quantity of water W demanded by a farmer in a given district in a certain period as an inverse function of its price *wp,* given the farm production possibilities and characteristics Q[5]:

$$W = f\left(wp;Q\right) \quad (3)$$

The amount of data requested depends on the level of detail chosen in a specific simulation.

For each type of farm considered, the following are always requested: soil and labour availability, separated into owned/family and rentable/external. The water table, reclamation fees and financial data covering capital availability, fixed costs and remuneration, are all linked to specific constraints and equations which are not used in the ST analysis.

Another set of data describes crops. These data are region specific and often vary from one farm to another (according to different production systems).

Crops selling price and subsidy are considered separately; this enables us to explore alternative policy scenarios.

Agronomic information describing possible rotation, commercial relations and political constraints is also present.

Another set of data is related to the sustainability indicators previously described.

Models enable us to analyse different irrigation techniques in terms of their efficiency and their labour and energy requirements.

Other coefficients describe water provision and price, set-aside requirements, and the remuneration of internal factors (land, labour and capitals) necessary to estimate the residual profit.

4. THE ANALYSIS

Three different analyses have been conducted considering respectively:

- The short-term horizon
- The long-term horizon
    - Dynamic (static long-term models)
    - Dynamic (multi-period techniques)

4.1. Short-term (static) analysis

In economic terms, the short term or run means a "period in which the firm can make only partial adjustment of its inputs to a change in conditions" (Begg et al., 1991).

[4] Water provision levels enable us to simulate an increasing pricing scheme, via blocked tariffs.

[5] Water demand can be derived via the parameterization of price or quantity.

The short-term analysis aims to estimate the immediate reaction of the farm to changes in water price or other parameters defined in the scenarios. The scenarios are perceived by the decision makers as certain and stable, and the possibility of farm restructuring is excluded, given that it would require extensive planning and lengthy implementation including the need for professional training and qualifications.

As a consequence, the following variables may be held constant:

- farm surface;
- technical resources (buildings, machinery, etc.);
- livestock;
- pluriannual crops (new planting is not possible);
- permanent labour (family and/or otherwise).

The possible choices therefore centre around the following aspects, which constitute variables:

- irrigation levels not requiring structural adjustment;
- farming techniques not requiring changes in technical resources;
- annual crop mix, included set aside or environmental measures.

Altogether, the variables that are allowed to change may be defined as those of the annual cropping plan.

In general, in the short-term static model, the farmer maximizes the MAUT objective function subject to technical, financial and policy constraints. The basic assumption is that farmers have all the necessary information.

As far as concerns the farm income target, this may be seen as the gross margin (fixed costs, such as depreciation, taxes, general expenses, wages for fixed and household labour, etc., are not taken into account).

4.2. Long-term (dynamic) analysis

In economic terms, long run means a "period long enough for the firm to adjust all its inputs to a change in conditions" (Begg et al., 1991).

The long-term analysis aims to estimate the water demand in relation to the farm's long-term process of adaptation. This horizon is particularly relevant when farm investments are taken into account. Most of them, in fact, take a long time to be implemented and to produce a return on the capital invested: orchards, being perennial, are a perfect example of this.

From the long-term point of view, the analysis can consider new production options which enlarge the existing series of feasible ones.

Technical innovation, including mechanisation, chemicals, new varieties like genetic modified crops (GM crops), etc., is also taken into consideration.

Within this framework, choices may also concern various aspects of farm organisation and management:

- variation of farm surface, by land market or rent;
- investment or dismissal of technical resources;
- increase or reduction in livestock;
- variation in the use of permanent labour;
- planting or dismissal of permanent crops;
- financial aspects;

- irrigation techniques;
- cropping techniques;
- livestock rearing techniques;
- crop combinations.

The common design for long-term models adopted is represented by a static long-run models, although some partners decided to implement alternative models as well, in order to adapt them to their traditional agricultural systems. So, in some cases the long-term models have been designed following the multi-period mathematical programming approach.

Figure 5.2. Time horizon and decision-making variables

			Time horizon	
			Short	Long
N. Ob.	1	Mono-objective	x	x
	> 1	MAUT	x	x
Decision variables		Crop mix change	yes	yes
		Irrigation level change	yes	yes
		Irrigation techniques change among existing	yes	yes
		New irrigation technique [investments decision]	no	yes INTEGER
		Farm enlargement	no	yes
		Labour employments [family and seasonal workers]	yes	yes
		Labour employments [structural]	no	yes

4.3. Long-term (multi-period) analysis

An innovative feature of this approach has been the application of multicriteria methodology and multi-period models to Guadalquivir River irrigated farming, where permanent crops, in particular olive groves, are very common.

The methodology is based upon a tried-and-tested technique using a farmer's surrogate utility function based on goal programming (see Amador *et al*., 1998) and developed for crop planning decisions, as described by Cañas *et al*., 2000 or Gómez-Limón & Berbel, 2000. We use this surrogate utility function to simulate decisions as close to reality as possible, as we try to mimic real crop distributions.

Following Gómez-Limón & Berbel (2002), once our use of the multicriteria additive utility function has been justified, we take the further step of assuming that the individual attribute utility functions are linear. Once we define this surrogate utility function, which is specified for each type of farmer, the weightings of the relevant criteria are used to simulate the long-term multi-period behaviour of farms under various scenarios.

According to previous studies (Attwood et al., 2000; McCarl and Spreen, 1997, etc.) long-term planning always needs the prior definition of certain relevant questions, the first of which being the starting date and final planning horizon. For agricultural farm management decisions governed by a policy of sustainability, activity has an unlimited horizon, although decision-makers need a planning period for management and financial considerations. We have taken 2002 as the starting year.

In our model, we wish to simulate the planting of trees (orchards and olives) and irrigation technique investment decisions, and the most limited decision in this sense is olive tree planting, given that these require a very long time to reach maturity. When we use shorter periods (as for fruit trees, such as peach, apples, etc.), olive are not taken into consideration, although this is contrary to the real-life behaviour which constitutes our frame of reference. One solution might be to consider the final value of investment in olive trees, but we have opted to use the long-term (40 years) period for simulation purposes, and to consider only the first ten years of simulation in our analysis. We will only show the first part of the period, because scenario analysis has been set for the year 2010, and because we do not feel confident about predicting beyond this horizon. Furthermore, the last years of the planning period may see instability and tree removal.

The third decision is to specify initial and final inventory conditions. In our model, initial inventory conditions are the area of trees planted and the drip-irrigated area, meanwhile final inventory is an open question.

The above definitions are quite straightforward, but the most difficult decision to make concerned the discount rate to be used in the Utility Function. Most studies, such as that of Bontemps and Couture (2002), only use the Net Present Value or the discounted value of cash flows as the variable to be maximized. Some of the authors study the problem of introducing risk into a long-term model (Barry, 1980; Bjornson, 1992; Bjornson & Innes, 1992; Amegbeto & Featherstone, 1992) through a risk premium in the discount rate, and we have based our choice on the CAPM (Capital Asset Pricing Model) model.

However, our model includes the profit objective along with other criteria relevant to decision-makers, and as we shall see later, most of the cluster analysed in the Guadalquivir Basin (Southern Spain) demonstrated a certain aversion to employing labour. This points out a methodological problem regarding the discount rate used to obtain the present value of objectives other than profit. We also have a practical problem in that with different discount rates being applied to the two criteria, the result is a change in relative preferences, due not to the psychological values of the farmer but to the mathematical application of the discount rate. For this reason, we finally decided to apply a discount rate to the Utility Function (which includes both objectives). Also, by discounting both objectives we are able to maintain the proportionality of the weights ratio during the planning period.

We are now going to define the model's components in greater detail.

4.3.1.- *Decision variables*

The key variable is X(t,c), which is defined as area for crop 'c' at year 't', and its application to annual crops is quite simple. However, there is an additional complexity regarding tree crops, as the year of plantation influences the criteria of cash flow and casual labour demand and the rest of the attributes, and therefore X(t,o), X(t,cit), etc. are vectors of characteristics according to the age of the plantation.

Z(t) is an instrumental variable representing the area where drip irrigation is introduced in place of the existing sprinkler system.

4.3.2.- *Objectives and weightings of the utility function*

In our particular case, the objectives to be estimated 'a priori' as important decision criteria, are the maximization of Net Present Value and the minimization of casual labour. We decided to include the second objective because of the difficulty in finding sufficient quantities of agricultural labour with experience (of, for example, irrigation scheduling and machinery management) in the area in question. Therefore, we have not included this objective in the computation of Net present Value (subtracting the cost of labour) because farmers are not aiming to minimize the cost of labour. Reality reveals that in many cases, although farmers offer employment, they do not get sufficient people to work on their farms in the area in question. In fact, most farmers have had to adopt drip irrigation because this is a labour saving device. To avoid double counting in the system, we measure both criteria using different units (euros/ha and man-days/ha). So, when farmers minimize employed labour, they automatically minimize the difficulty of find large numbers of workers rather than it's the cost of labour. Farmers have two ways of reducing the quantity of casual labour: by changing the cropping pattern, and by changing irrigation technology.

1. *Maximize net present value (NPV).*

We use the average cash flow for the last 5 years (FCc) as the estimator of economic criteria.

$$FC = \sum_{c=1}^{q} FC_c * X_c$$

where Xc is the area per crop (c=1,q) per year.

We need to use Cash Flow as we are going to calculate NPV, which produces certain advantages when CF is used instead of profit.

2. *Minimization of casual labour (MO).*

The scarcity of casual labour is the main reason for the rapid adoption of the drip irrigation system mentioned in the previous section. Sprinkler systems require a much greater labour input than drip irrigation (in general, drip irrigation needs 20% fewer hours/ha than sprinkler). When this activity is performed by the farmer himself, the convenience of irrigation scheduling and performance is greatly appreciated by both full-time and part-time farmers. Computation of this criterion is straightforward.

$$MO= \sum_{c=1}^{q} MO_c * X_c$$

where Xc is the area per crop (i=1,q) per year and MOc is the labour needed per crop, per hectare, per year.

4.3.3.- *Present Value Utility Function*

As we mentioned above, in the long term we need to maintain exact proportions in the weightings of the two criteria in question (Cash Flow vs. Casual Labour); so we are going to use a Utility Discount Rate in the Present Value Utility Function (PVUF) to compare parameters throughout the period. This is justified by the preference of present Utility (consisting of the maximization of NPV plus the minimization of casual labour) versus future Utility. As we said before, we have based our choice on the CAPM (Capital Asset Pricing Model) model, in which Segura y Ribal (2002) have analysed the rate of interest implicit in the valuation of farm land in Spain and irrigated areas, producing useful figures for our purposes. They calculated a discount rate of 7.98%, including a risk premium, for irrigated farming in Andalucía, which is where the Guadalquivir basin is located. This rate is the sum of a free risk rate and a risk premium. The first is the profitability of Government Bonds (3.15%) and the second is the risk premium of irrigation in Andalucía (4.83%), calculated according to Sharpe (1994).

Our adaptation of the short-term static model is therefore as follows.

$$\textbf{Max.}\quad PVUF = w_1 * NPV / (f_{NPV*} - f_{NPV,LAB}) - w_2 * LAB / (f_{LAB,NPV} - f_{LAB*})$$

NPV and LAB are computed by hectare in the following way:

$$NPV = \sum_t \sum_c \left(\frac{X(t,c) * FC(t,c) - z(t) * 1{,}500}{(1+r)^{t-1}} \right) ?$$

$$LAB = \sum_t \sum_c \left(\frac{X(t,c) * MO(t,c)}{(1+r)^{t-1}} \right)$$

where

r is the Utility Discount Rate.
t varies from 1 to 40,
c is the crop
FC(*t,c*) is Cash Flow per year and hectare
Z(*t*) is the year of substitution (hectares) of drip for sprinkler and 1,500 is the investment (€/ hectare) needed to make this change.
MO(*t*,*c*) is the casual labour input per crop per year.

4.3.4.- *Constraints*

Finally, there are some constraints on the model, some of which are 'cluster'-specific but are described below in global terms:

- Area constraint: $\sum_c (Xc)$?=100, so the result Xc will be a percentage; this is obviously maintained every year.
- CAP regulation: According to the EU's Agenda 2000, set-aside needs to be a minimum of 10% of subsidized annual crops and, in the case of voluntary land retirement, a maximum of 20%. Furthermore, production of durum wheat is limited to traditional growers, and so we limited it to the maximum reached in the period from 1992/93 to 2000/01, likewise with cotton (expressing such limits in percentage terms).
- Crop rotation: We have used a frequency constraint so that any annual crop is less than 50% of the total grassed area. Some further succession constraints have been included, according to farming practice as defined in the field research, e.g. after cotton or sugar beet, permitted crops include wheat and sunflower, whereas corn is not grown.
- Vegetables: there are some vegetable processing factories in the area and their capacity is increasing, but it is assumed that traditional levels of production will be maintained for the next few years.

These are customary constraints and were used for the short-term static model; however, the following constraints are specific to the multi-period programming model.

- Financial constraint: any crop plan should guarantee the farmer an income which is at least the same as the rental value of the land (396.5 €/ha in this area). This constraint is necessary because land rent has not been included in FC. The minimum level in table 6 is multiplied by 100 because the annual rental value is calculated for an ideal farm of 100 hectares, in order to obtain percentages figures.
- Water supply: the theoretical supply in the irrigated area is 5,000 m^3/ha (the maximum quantity of available water).
- Initial inventory conditions: these are cluster-specific and set the initial area of olives, citrus fruit and drip irrigation in year 0 (2002).

- Crop growth links: it is obvious that the age of a tree planted in any one year affects its age in subsequent years, but this type of equation needs to be stated to avoid errors.
- Irrigation technology: the use of drip irrigation may increase but this implies an investment cost and reduces the area under sprinkler systems.

5. MODEL IMPLEMENTATION AND ANALYSIS OF RESULTS

The parameter-definition phase was conducted according to the previous scenario-definition phase, on the basis of national and regional data.

The EU *Farm Accountancy Data Network* (FADN) represents the main source for representative region and farm definition, although it was supplemented by other sources, in particular primary data collected from ad hoc surveys and necessary in order to find proper technical coefficients for the calibration of the mathematical models.

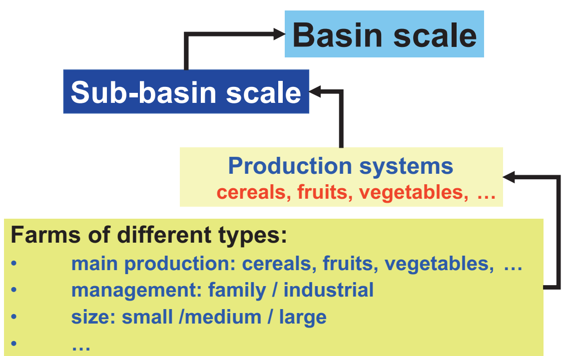
Validation of the models was conducted in order to ascertain the capacity of the tool to describe the observed reality.

The final part of the research programme includes the use of the validated models to analyze the impact of WFD and CAP reform according to the previously defined scenario.

Finally, the project's additional activities include the extrapolation of microanalysis to regional analysis. This issue is dealt with according to the specific decisions made at the local level in defining representative areas and farms.

The approach followed is summarized in figure 5.3 below.

Figure 5.3. Aggregation and scale



Aggregation at the local level, and the aggregate effects on the environment, are not always straightforward and may only be properly estimated with reference to the specific conditions within each area. In particular, caution is needed when summing up the impacts that actually produce interaction and potential circular effects at the basin level.

More information is available in the national chapters.

The innovative approach adopted has been applied simultaneously to various different regions representing the most important irrigated areas in Europe.

Finally, mention should be made of the fact that a Decision Support (DS) called DSSIR (Bazzani et al., 2002) to run part of these models is currently being developed. The program is characterized by a user-friendly interface, a modular and open architecture, and an effective interfacing with other models. DSIRR operates as a Windows application using GAMS (General Algebraic Modelling System) as the optimization tool. The flexible model specification and the internal database of irrigation technologies and crops, make the DS a powerful scenario manager which will facilitate the extensive application of this methodology.

6

The case of the River Guadalquivir Basin (Southern Spain)

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1. Background

Irrigated agriculture in Spain occupies 18.3 % of the country's total cultivated area and is responsible for 55 % of Final Agricultural Production. Although the variation is very large, an irrigated hectare produces an average of 6.5 times as much as a rain-fed hectare. The importance of irrigation is very significant in a Mediterranean country like Spain, because of marked seasonal water shortages. Because southern Spain has an arid climate that makes irrigated agriculture more productive than rain-fed agriculture, we have selected for our study the basin of the Guadalquivir Valley the south of Spain, where 597,980 hectares are under irrigation. A wide range of crops are cultivated in this area are very diversified, including low value-added crops and those dependent on CAP subsidies with high value-added crops that do not receive CAP subsidies such as vegetables and the new intensive olive groves. Table 6.1 shows the irrigated area and types of system in use, and we can see that the Guadalquivir Valley has a significant percentage of drip irrigation. At 35.1%, this is above the Spanish average, which is the more remarkable when we remember that under the "irrigation" designation there are some areas in the Central North where water quotas are virtually limited to late spring cereals, with low consumption per hectare.

Table 6.1. Irrigated area by irrigation system

System	Spain		Guadalquivir Basin	
	Ha	%	Ha	%
Gravity	1,980,838	59.22	270,099	45.20
Pressure	800,945	23.95	117,639	19.67
Drip	562,854	16.83	210,242	35.13
Total	3,344,637	100%	597,980	100%

Source 'Plan Nacional de Regadíos ' (1999) and 'Inventario y Caracterización de Regadíos de Andalucía' (1999)

2. OBJECTIVES

This study applies scenario analysis of the consequence of changes in European policy to the possible evolution of agriculture in a river basin, using a set of indicators. We aim to contribute to the evaluation of the environmental impact of agriculture through the use of models based on ecological, economic and social sustainability indicators. The present 'status quo' scenario is tested against several alternative scenarios under which implementation of the WFD would lead to an increase in water price, while agricultural policy reforms would affect pesticide use, bring about a rise in labour costs, reduction in public support and reduce prices, etc. This paper will utilize this framework to study the typical irrigated systems of the Guadalquivir Valley and subsequently integrate all the systems into a global study at basin level.

The methodology employed is based on multicriteria methodology applied to multiperiod models. This is a significant innovation, given that multicriteria models have virtually always been applied to single-period static models. After we have obtained simulated crop plans for each cluster in each area of the basin in which general and more frequent irrigation is practised, we integrate the simulated cropping patterns through a weighted sum of areas in order to obtain the representative cropping pattern of the most important agricultural systems in the basin. However, there are two other representative agricultural systems that must be included in the basin, and these are localized in the Upper and Lower Valleys of the river. In these, traditional olive groves and rice respectively occupy almost 100% of the surface and therefore, it is not necessary to simulate alternative crops because in the first case, the only alternative is rain-fed olives, and in the second case there is no agricultural alternative because the soil is saline and the only possibility is to abandon agriculture and dedicate the land to nature reserve purposes, by extending the existing Doñana National Park.

This procedure gave us the weighted average crop plan in the Guadalquivir Basin, including the three mean irrigated agricultural systems: General, Extensive Olive and Rice. From this representative cropping pattern we obtained the values of indicators in Scenario 0 (Agenda 2000 and water price zero).We then proceeded to perform the simulation and integration again in each of the defined scenarios. In these scenarios we have combined water pricing with agricultural policy reform and in each scenario water price goes up by a percentage with respect to the present price (we have started from the assumption that the present water price is equal to the current cost of water (in €/m^3)), because in reality, the price of water is zero.

3. CASE DESCRIPTION AND CLUSTERS DEFINITION

We analyze the implications various policy scenarios for the irrigation of one of the most important basins in Spain: the Guadalquivir Valley in Andalusia. The study has been performed on three existing kinds of irrigated agricultural system: General Irrigation, Irrigated Extensive Olive and Rice (see figure 6.1). The first system is localised in the mid-Guadalquivir Valley. It is the most generalized system and for this reason, we found it necessary to select some representative irrigated areas; Fuente Palmera, Genil-Cabra, Bembézar M.Dª and El Villar,in which to carry out a subsequent integration of the results for the mid-Guadalquivir Valley, under a range of policy scenarios. Irrigated areas were selected at random. In these areas there is a wide variety of irrigated crops, but the most important are cotton and other extensive spring crops such as sunflower and maize; wheat, intensive olive, citruses, peaches and fresh vegetables complete the crop pattern. The second system, which occupies 25.13% of total surface of the basin, comprises the extensive olive monoculture of the Upper Guadalquivir Valley. The third system is rice, which is irrigated by flooding and is found in the Lower Guadalquivir Valley, where land is saline and marshy. This crop occupies 6% of the total area of the basin and is the only possible crop in this area, because of the type of soil.

Figure 6.1. Agricultural systems in the River Guadalquivir basin

Source: Adapted from www.chguadalquivir.es

It is normal when modelling an area to build various models, and the most frequently used system of classification is size. However, we follow a system of characterization that is based upon behaviour as reflected by crop-planting decisions, regardless of size. Nevertheless, there is always some correlation between crop plans and farm structure, but we believe that the farmer's personal values and socio-economic characteristics have greater influence in crop decisions than farm size by itself. For this reason, our classification starts with the results of a questionnaire that apply cluster techniques to crop decisions. We use SPSS v8.0 with a hierarchical classification based upon Euclidean distance. The results are several clusters which have a satisfactory degree of homogeneity in the irrigated areas of the mid-Guadalquivir Valley that we studied.

The clusters found in each of the irrigated areas of Medium Valley are shown in table 6.2.

Table 6.2. Clusters of "General Irrigation System"

Irrigated area "Fuente Palmera"

	Cluster: A Cotton	Cluster B: Wheat	Cluster C: Corn	Cluster D: Groves
% farmers	19.7%	31.5%	32.9%	15.7%
% area	8.3%	45.8%	32.4%	13.3%
Age	54	55	49	46
% income from agriculture	80%	40%	70%	40%
Average size (ha)	8.3	28.8	19.6	17.0
Median size (ha)	5.5	6.7	7	4
Total area (ha)	125.2	691.3	489.7	201.9
Dominant irrigation system	drip	sprinkler	drip	drip
MEAN CROP	Cotton (85.8%)	Wheat (52.8%)	Corn (42.6%)	Olive (59.2%)

Irrigated area "Genil-Cabra"

	Cluster A: Conservative	Cluster B: Commercial	Cluster C: Intensive olive	Cluster D: Vegetables
% farmers	49.3%	21.5%	17.7%	11.4%
% area	53.3%	22.2%	16.4%	8.0%
Age	52	49	58	47
% income from agriculture	100%	100%	100%	100%
Average size (ha)	24.8	23.9	21.4	16.2
Median size (ha)	15	14.8	11	2.8
Total area (ha)	972.6	406.2	298.9	146.2
Dominant irrigation system	sprinkler	sprinkler	drip	sprinkler
MEAN CROP	Cotton (33.1%)	Cotton (44.5%)	Olive (64%)	Vegetables (60.2%)

Irrigated area "Bembézar M.D[a]."

	Cluster A: Corn	Cluster B: Diverse	Cluster C: Fruit	Cluster D: Vegetables
% farmers	26.2%	37.5%	21.2%	15.0%
% area	18.9%	47.8%	20.6%	12.7%
Age	53	52	50	47
% income from agriculture	90%	90%	100%	100%
Average size (ha)	16.2	28.5	21.7	19.2
Median size (ha)	6.0	19.6	14.0	15.3
Total area (ha)	347.92	880.05	380.55	233.52
Dominant irrigation system	gravity	gravity	drip	gravity
MEAN CROP	Corn (57.7%)	Cotton (52.5%)	Citrus (50.3%)	Vegetables (55%)

Irrigated area "El Villar"

	Cluster A Commercial	Cluster B: Conservative
% farmers	64.3%	35.7%
% area	48.0%	52.0%
Age	48	55
% income from agriculture	100	100
Average size (ha)	19.7	38.5
Median size (ha)	8.5	16
Total area (ha)	532.6	577.8
Dominant irrigation system	drip	drip
MEAN CROP	Cotton (73.5%)	Cotton (49.0%)

4. THE MODEL

We have built a model, with yearly decision intervals and two farmer's objectives in the main agricultural system of the Guadalquivir basin. This multiperiod model is based upon a multicriteria objective function and has been developed for the Guadalquivir Valley, dividing the irrigated area into homogeneous types of farming as identified by cluster analysis. The model is applied to different future scenarios with a time horizon of ten years and different farming environments. However, the model continues to simulate out to a 40-year horizon in order to avoid 'border' or 'transition' results. A set of sustainability indicators has been evaluated for the model.

The methodology employed to build this model has been detailed in chapter 5, "Methodology".

4.1. Components of the model:

4.1.1.- *Decision variables*

X(t,c) is defined as the area given over to crop 'c' in year 't', and its application for annual crops. X(t,o), X(t,cit), X(t,pea), X(t, asp), defined as areas for perennial crops, are vectors of characteristics as a function of the age of the plantation. Z(t) is a instrumental variable which represents the area where the irrigation system is changed to drip from the existing sprinkler system.

4.1.2.- *Multicriteria and multiperiod utility function*

- Objectives and weightings of utility function

After applying the bi-criteria model to the clusters founded in each area of General Irrigation System we obtained the results (weightings of utility function) shown in table 6.3, where we can see the results of applying the methodology explained in section 4.3. of chapter 5 "Methodology", to the crop area and the criteria values. These weightings were obtained by comparing projected versus actual result, and we have the 2001/2002 data as a validating set, therefore although the weights were obtained for the 'short term' they will be used for long-term simulation.

Table 6.3. Criteria Weightings by cluster in General Irrigation System

Fuente Palmera			
Cluster A: Cotton	Cluster B: Wheat	Cluster C: Corn	Cluster D: Groves
99.5% FC – 0.5% MO	83.8% FC – 16.2% MO	96.3% FC – 3.8% MO	99.5% FC – 0.5% MO
Genil-Cabra			
Cluster A: Conservative	Cluster B: Commercial	Cluster C: Intensive olive	Cluster D: Vegetables
65.3% FC – 34.7% MO	75.9% FC – 24.1% MO	98.3% FC – 1.7% MO	94.6% FC – 5.4% MO
Bembézar M.Dª			
Cluster A Corn	Cluster B: Diverse	Cluster C: Fruit	Cluster D: Vegetables
96.4% FC – 3.6% MO	90.4% FC – 9.6% MO	97.4% FC – 2.6% MO	82.6% FC – 17.4% MO
El Villar			
Cluster A: Commercial		Cluster B: Conservative	
95.3% FC – 4.7% MO		64.6% FC – 35.4% MO	

Source: Authors' own data

The weightings found were consistent with the features of the crops, e.g. in irrigated area of Fuente Palmera, the wheat-oriented cluster (B) has a higher weight for labour minimization than groves (D) or cotton (A) oriented clusters.

- Present Value Utility function

As we have mentioned, in the long term we need to maintain the correct proportions in the weightings for the two criteria considered (Cash Flow vs. Casual Labour). For this reason we use a Utility Discount Rate in the Present Value Utility Function (PVUF) to compare parameters throughout the period. This is justified by the preference for present Utility (made up by maximization of NPV plus minimization of casual labour) as against future Utility. As mentioned above, we based our choice on the CAPM (Capital Asset Pricing Model) model, in which Segura & Ribal (2002) and Ribal (2003) analyse the discount rate implicit in the valuation of farm land in Spain and irrigated areas, estimating a rate of 7.98%, (including a risk premium) for irrigated farming in Andalusia, where our case study is located. This rate is the sum of a free risk rate (Government Bonds i.e. 3.15%) and a risk premium (4.83%) calculated according to Sharpe (1994).

Our adaptation of the short-term static model is therefore as follows.

$$\textbf{Max.}\quad PVUF = w_1 * NPV / (f_{NPV}{*} - f_{NPV,LAB}) - w_2 * LAB / (f_{LAB,NPV} - f_{LAB*})$$

4.1.3.- *Constraints*

The constraints considered in the model (table 6.4), some of which are cluster-specific, are in global terms: Area constraint, CAP regulation, Crop rotation and Market for vegetables. These constraints are classical and were used for the short-term static model; however, the following kinds of constraint are specific to multiperiod programming: Financial constraint, Water supply, Inventory initial conditions, Crop growth links, Irrigation technology (drip irrigation may increase but this implies an investment cost and reduces the area under sprinkler system), and Limits in agro-chemical use.

4.1.4.- *Attributes: Environmental and socio-economic indicators*

Multicriteria models use the term ‘attribute’ for any relevant value of the system. We have described the attributes that belong to farmers’ decision criteria, integrated in the objective function, in addition to the attributes that define the feasible set by integrating the constraints. This section is devoted to the remaining attributes, which form the ‘indicators’. These variables neither constrain the farmer nor are considered for optimisation by the decision-maker (farmer), but they are relevant to measuring the impact of agriculture (for policy-makers and society as a whole).

Our specific aim was the selection of a limited number of parameters that can be fed into the mathematical models that have been developed in the quantitative phase in order to evaluate the impact on irrigated agriculture according different policy scenarios. The indicators selected to check and control the sustainability of agriculture at farm level have been defined in chapter 5: “Methodology”, section 2.2.

Table 6.4. Summary of generic constraints of the model

$\sum_{c} x(t,c) = 100$	∀t	Land
$\sum_{c} \left(x(t,c) * FC(t,c) - z(t) * 1500 \right) \geq 100 \times 396.5$	∀t	Financial
x(t,set-aside) ≥ 10% ∗ (x(t,durum-wheat) + x(t,wheat) + x(t,durum-wheat-dry) + x(t,wheat_dry) + x(t,sunflower) + x(t,sunflower_dry) + x(t,corn)	∀t	CAP
x(t,set-aside) ≤ 20% ∗ (x(t,durum-wheat) + x(t,wheat) + x(t,durum-wheat_dry) + x(t,wheat_dry) + x(t,sunflower) + x(t,sunflower_dry) + x(t,corn)		
x(t,durum-wheat) + x(t,durum-wheat_dry) ≤ (specific maximum)		
x(t,cotton) ≤ (specific maximum)		
x(t,sugarbeet) ≤ (specific maximum)		
$x(t,c) \leq \frac{50}{100} * \left(100 - \sum_{o} x(t,o) - \sum_{cit} x(t,cit) - \sum_{pea} x(t,pea) - \sum_{asp} x(t,asp) \right)$	∀t, c, o, cit, pea & asp	Frequency
x(t,crop1) ≤ x(t,crop2) + x(t,crop3) + x(t,crop4) + x(t,crop5)	∀t	Succession
x(t,vegetables) ≤ Max_vegetables by cluster	∀t	Vegetables
x(t,olive_year0) + x(t,olivo_year0_dry) = cluster olive area	∀t	Initial multiannual area inventory
x(t,citrus_year0) = cluster citrus area		
x(t,peach_year0) = cluster peach area		
x(t,asparagus_year0) = cluster asparagus area		
x(t,o) = x(t-1,o)	∀t, o, cit, pea & asp	Age of plantation
x(t,cit) = x(t-1,cit)		
x(t,pea) = x(t-1,pea)		
x(t,asp) = x(t-1,asp)		
drip0 = existing drip by cluster	∀t	Drip irrigation
Water demand(t) ≤ Water endowment	∀t	Water supply
Drip(t) = z(t) + Drip (t-1)	∀t, drip_ crops	Irrigation technology
$\sum_{drip} x(t, drip\_crops) \leq drip0 + Drip(t)$		
Pesticide(t) ≤ Max_pest	∀t	Agro-chemical use
Nitrogen(t) ≤ Max_N		

4.1.5.- *Integration of results of simulation*

The objective of this study was thus to built a realistic model capable of simulating probable developments following potential changes in the EU's water policy (WFD) and agricultural (CAP reform) scenarios. We therefore employed a reliable methodology to define the consistent or linked scenarios for both policies.

We obtained the weighted medium crop plan in the Guadalquivir Basin, including the three existing agricultural systems. The estimate of scenarios for the future of the European Irrigated Agriculture thus differed from the status quo represented by Agenda 2000 and water price zero.

The simulation and integration were thereafter repeated for each scenario, combining water price (starting with the assumption that the current water price is equal to the cost of water because the price of water is actually zero) with alternative reforms of agricultural policy. Scenarios are detailed in the previous chapter, "Scenario definitions". The reference time horizon was set to 2010 and the individual scenarios are briefly characterized in our study as:

Scenario 1 (World Agricultural Markets). In this context the CAP subsidies completely disappear and prices of outputs fall by between 10% and 15%. On the other hand, crop yields increase thanks to modern technology. The prices of most agricultural inputs fall, but the price of water goes up by 22.5 % vis-à-vis its current price. There are no limits on agro-chemical use.

Scenario 2 (Global Agricultural Sustainability). CAP subsidies are lowered by 5 and 20% (except for sunflower and set-aside). Output prices fall by between 5% and 10% (except for vegetables). On the other hand, crop yields increase as a result of technological innovations. The prices of most agricultural inputs increase and the water price goes up by 40%. The use of chemical inputs is cut by 30%.

Scenario 3 (Provincial Agricultural Markets). CAP subsidies remain at the same level as under Agenda 2000 for wheat, sunflower and set-aside, but in the case of other crops they fall by 5 - 10%. Olive oil, sugar-beet and cotton prices decrease by between 5 and 10%, while other crop prices, mainly vegetables and fruits, increase. the prices of inputs suffer a considerable increase (5% to 25%) and the price of water rises by 12.5 %. There are no limits on agro-chemical use.

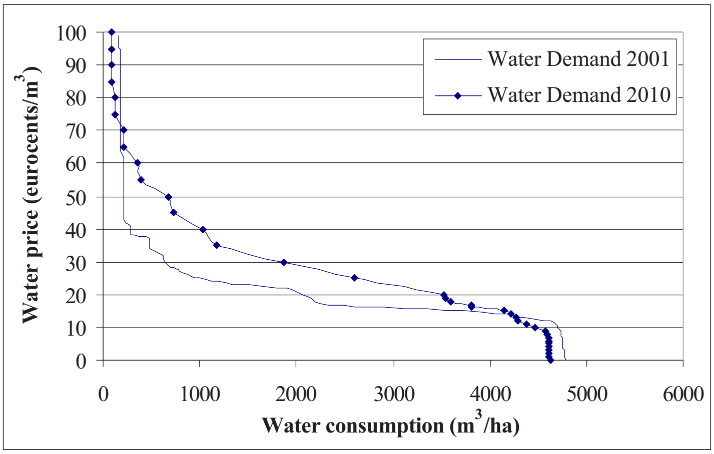
Scenario 4 (Local Community Agriculture). All agricultural subsidies increase between 5% and 15%, except for maize. All output prices rise by between 5% (sunflower) and 25% (vegetables). However, prices of inputs also increase by between 15 and 60%. Water goes up by 50% and chemical inputs fall by 35%.

Even though they consist mainly of a 'storyline', the quantitative indicators which illustrate the direction and rate of the changes of the relevant parameter to be used in the simulation phase were estimated. Such coefficients have been quantified considering the combination of Agricultural and Water Policies scenarios corresponding to the national and local specificity of the study. In particular we defined their impact on irrigated agriculture with respect to farming systems affected by the reform, profitability of irrigated crops, changes in the area dedicated to given crops, trends in employment, water consumption, fertiliser and pesticide use, etc.

5. INTEGRATED BASIN WATER DEMAND & IMPACT OF WATER PRICING UNDER AGENDA 2000

After obtaining the agriculture water demand curve, we obtained an integrated basin water demand function based on simulated data and using the model in the current context (Agenda 2000). Figure 6.2 shows the curve for the River Guadalquivir basin under the present scenario, at the time when we obtained the data (December 2001) and in the future (2010), under an hypothetical rising water tariff and the current Agenda 2000 regulations.

Figure 6.2. Integrated River Guadalquivir basin water demand function



The Integrated Guadalquivir Basin Water Demand Function shows an initial almost totally inelastic segment. In 2010, this first segment would be between 0 and 9 eurocents/m^3 and water consumption at these price extremes would be 4,621 and 4,584 m^3/ha, respectively. Within this segment, farmers' income, contribution to GDP and level of employment would exceed current values, and at the same time, water consumption and pesticide usage would be less.

However, when the water price reaches 10 eurocents/m^3, there is an appreciable reduction in water consumption in comparison with the current level (-329 m^3/ha). This point is the beginning of the second segment, whose principal feature is a clear elasticity. At 11 eurocents/m^3, farm income is slightly lower than it was in 2001 (1,660 €/ha), but the contribution to GDP is still considerably greater, increasing by 22%, and labour input will have increased by 36.8% (from 15 to 23.6 man-days/ha). The reduction in water demand is progressive through the curve, for example, when the price of water is 13 eurocents/m^3, water consumption is around 4,277 m^3/ha; when it reaches 15 eurocents/m^3, water consumption is 4,157 m^3/ha, etc. The curve becomes inelastic again when the price of water reaches 85 eurocents/m^3.

The Rice System tends to make the water demand function less elastic, because the only option for farmers when water price increases is not to irrigate, and unirrigated rice is not viable under the climatic conditions of the basin. When the price of water reaches 16 eurocents/m^3, rice would disappear because farmers' income does not approach the economic minimum for farmers in the basin (396.6 €/ha), and there is no possibility of producing other crop because of the special characteristics of the land (saline and flooded). At 16 eurocents/m^3, therefore, there is an appreciable reduction in water consumption in the basin and the demand for water is now 3,810 m^3/ha.

We can observe a water saving in the future (2010) accompanied by socio-economic improvements. Meanwhile, the water price does not reach 13 eurocents/m^3, thanks to a significant decrease in traditional industrial crops in favour of intensive olive and fruit groves, and the water demand function associated with these crops is very inelastic because the only possibility that farmers have when the water price increases significantly is not to irrigate their trees. In the first case, olive is a crop that can well be grown without irrigation (albeit with lower yields) and in the second case (fruit trees), the only possibility would be to pull them up. In the case of traditional or extensive olive cultivation, the change from irrigated to rain-fed extensive olive groves would occur when the water price reaches 23 eurocents/m^3, when mean water consumption in the basin would be around 2,700 m^3/ha. In general, the evolution of the cropping pattern would be in the direction of 20% of fruit and intensive olive groves, while annual crops (except vegetables) decrease.

Finally, we can see the water demand function for 2001 (when we obtained the data for this study) in figure 6.3. Between 0 and 12 eurocents/m^3, the curve for 2010 shows water savings vis-à-vis the curve obtained in 2001. At a water price of 13 eurocents/m^3 both curves meet at a level of consumption of 4,277 m^3/ha.

A rising water price has several kinds of socio-economic and environmental impact, as figures 6.3 and 6.4 show.

Figure 6.3. Socio-economic impacts in the River Guadalquivir basin

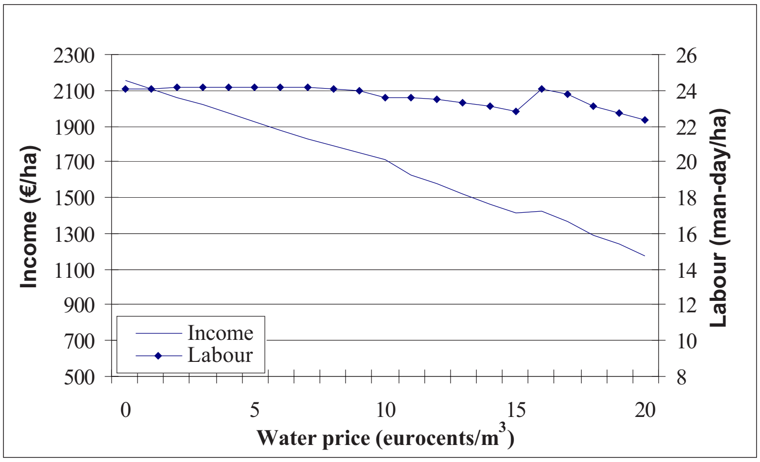
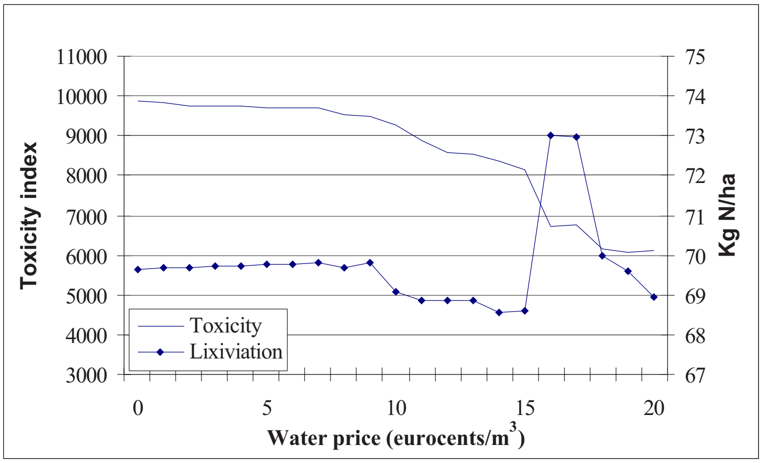


Figure 6.4. Environmental impact in the River Guadalquivir basin



6. RESULTS BY SCENARIO

We wish to emphasize that future scenarios are intended to be merely prospective; i.e. they are not deterministic realities. Therefore, the results of these scenarios should be understood as feasible and potential interval ranges.

6.1. Crop mix

In table 6.5 we can compare the resultant integrated cropping pattern of Guadalquivir basin in 2010 under different scenarios, as defined in section 4.4. figure 6.5 show us the evolution of crops under each scenario, by groups (cereals and oleaginous crops, industrial crops, vegetables and olive and fruit groves).

Table 6.5. Integrated cropping pattern of River Guadalquivir basin under different scenarios (%)

Crop	2001	2010				
		Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Wheat	10	12.3	15.4	3.5	14.6	9.9
Corn	13.4	3.3	19.6	9.5	13.2	7.7
Cotton	17.4	20.5	0	16.7	9.5	22.3
Rice	6	6	6	6	6	6
Sunflower	5.9	0.4	2	11.1	0.4	17.4
Sugarbeet	1.1	2.6	8.2	8.2	3	0.3
Intensive olive	7.9	20.4	22.9	21.2	16.4	8
Extensive olive	25.1	25.1	25.1	25.1	25.1	25.1
Citruses	5.3	10.5	0.3	8.5	8.1	9.6
Peaches	0.9	19.1	22.1	8.8	21.5	7.8
Potatoes	1.9	3.9	4.1	4.8	4.1	4.8
Onions	0.3	1.5	1.5	1.9	1.5	1.9
Garlic	1.8	1.2	0.9	0.9	1.7	1
Asparagus	0.4	0.9	0.9	1	0.9	0.7
Peppers	0.7	1.3	1.3	1.3	1.3	1.3
Set-aside	1.8	2.2	0.7	2.6	3.8	6.4

Scenario 0 (Agenda 2000 or Status quo). This is the scenario under which cereals and oleaginous crops decrease most in comparison with the 2001 cropping pattern. On the other hand, groves intensive olive, extensive or traditional olive and fruit trees) increase in this scenario more than in the others, occupying more than 70% of the total irrigated area. Industrial crops (cotton and sugar-beet) would continue to play an important role, even higher than in 2001. In vegetables, the trend is similar to the past; there are thus fluctuations in cultivated area but the tendency is for this to increase.

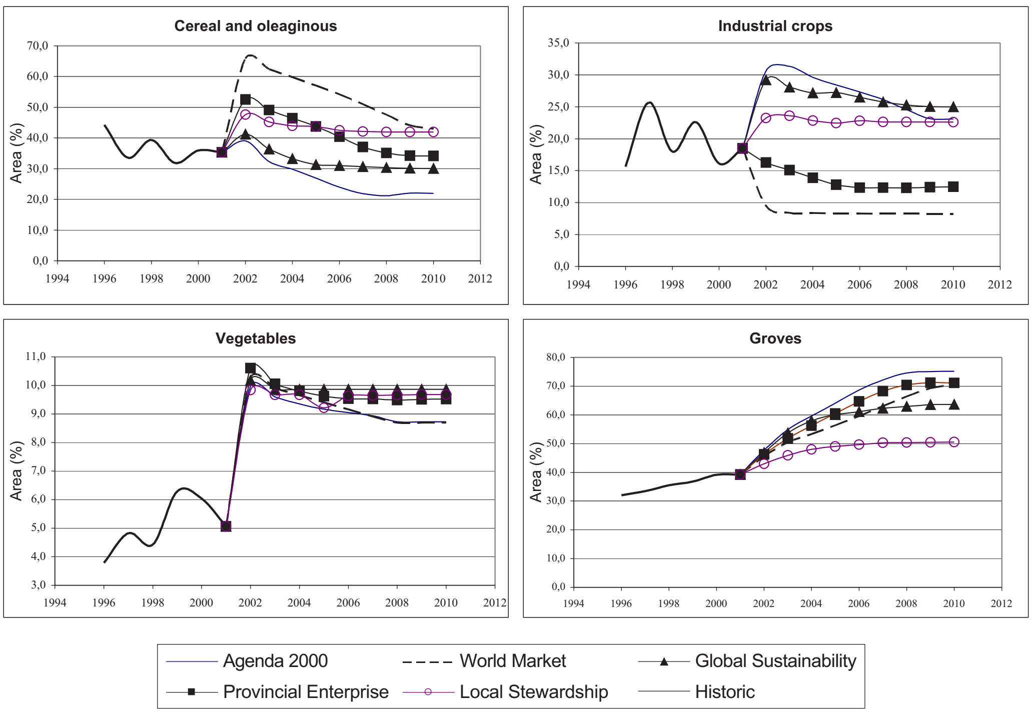
Scenario 1 (World Markets). Cereals and oleaginous crops tend to maintain the same tendency as in the past, i.e. variable but maintaining an important presence, around 43% at the end of the period under study (in 2001 this group of crops occupied 35.5% of the total irrigated area in the basin). On the other hand, industrial crops become mush less important, until they occupy only 8% of the irrigated area, mainly because cotton would disappear after elimination of its subsidy. Vegetables show a very similar trend to that of scenario 0 and groves, as in other scenarios, show a curve with a positive slope, reaching in 2010 70% of the total irrigated area.

Scenario 2 (Global Sustainability). Cereals and oleaginous crops decrease significantly, falling to 30% of irrigated area in 2010. Industrial crops (cotton and sugar-beet) will be slightly more important than at present. Meanwhile, groves show a growth curve with a positive but minor slope than most of the scenarios, reaching 38% of the total irrigated area by 2010. Under this scenario, vegetables would play the most important role at10%.

Scenario 3 (Provincial Enterprise). Cereals and oleaginous crops are as important as in 2001 and industrial crops decrease by 6% as subsidies disappear. in this scenario, surface increase most with the exception of scenario 0 (Agenda 2000).

Scenario 4 (Local Stewardship). In 2010, the cropping pattern under this scenario is the most similar to the 2001 crop mix (except for the vegetables group, which doubles its area in 2010). This is because under this scenario, crop subsidies would increase in comparison with 2001.

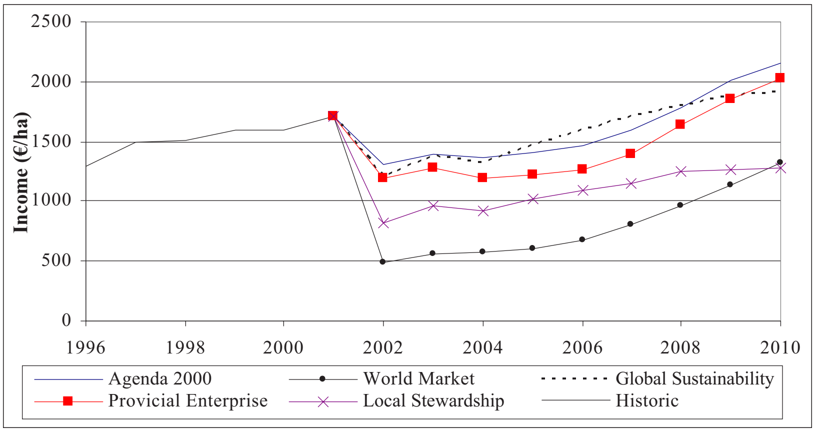
Figure 6.5. Evolution of crops by groups under different scenarios



6.2. Economic balance

Where farm income is concerned it is possible to see from figure 6.6 that Scenario 0 (Agenda 2000) would be the best scenario for farmers because rent of farmers in 2010 improves +20.3 %, respect to 2001. Scenarios 3 and 2 offer the second best farm incomes, with increases of 15and 10.2% respectively, while scenarios 1 and 4 show important reductions of -23.1 and -25.3%.

Figure 6.6. Integrated River Guadalquivir basin farm income (€/ha)



From the point of view of the "Contribution to Gross Domestic Product" indicator, however, in 2010 each scenario will reach a higher level than in 2001. Scenario 3 generates most wealth in 2010, followed by Scenarios 0, 2, 4 and 1 in that order (figure 6.7).

Figure 6.7. Integrated River Guadalquivir basin contribution to GDP

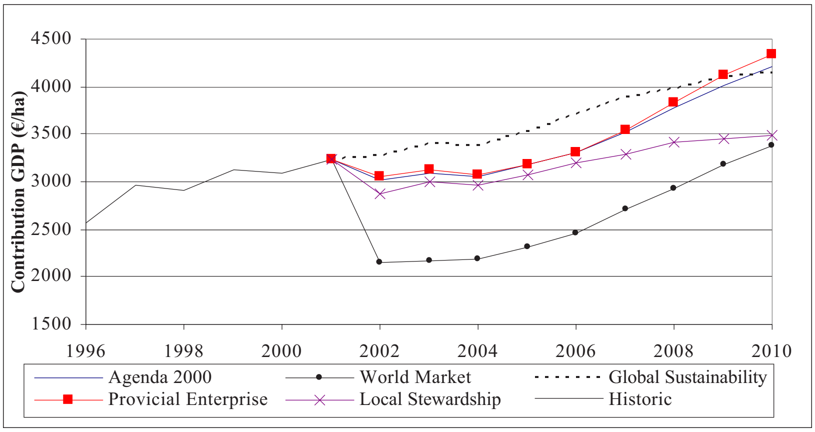


Figure 6.8. Integrated River Guadalquivir basin direct payments

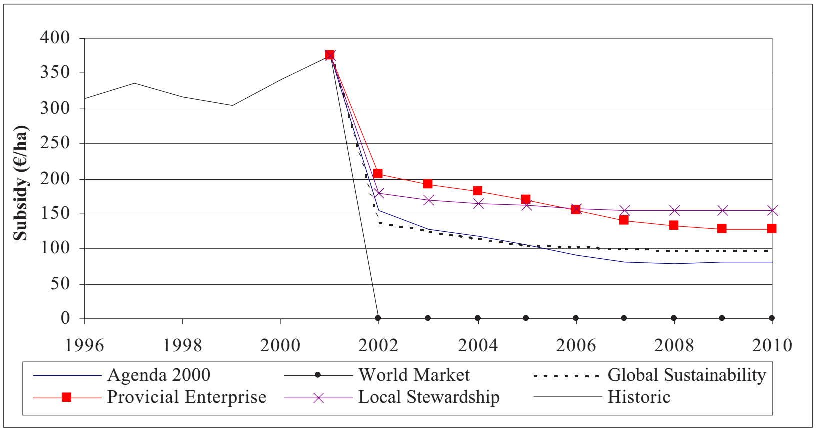
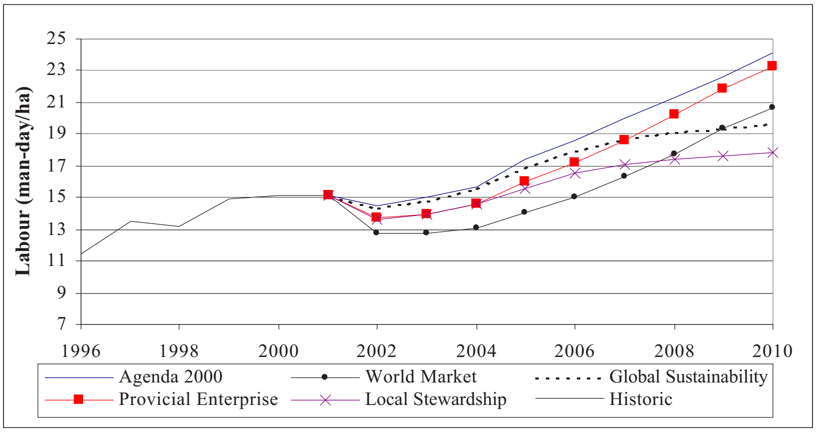


Figure 6.8 shows that Scenario 4 (Local Stewardship) is the most dependent on direct payments, a result that we regard as negative. On the other hand, we have Scenario 1 (World Market), where subsidies are zero. In general, however, direct payments will be smaller in every scenario in 2010 than in 2001, because the areas dedicated to cereal and oleaginous crops tend to decrease while the areas planted to fruit and olives groves tend to increase.

6.3. Social impact

The demand for agricultural labour is higher in Scenarios 0 and 3, once again because of the increase of fruit and olive groves (very labour-intensive), followed by Scenarios 1, 2 and 4. In general, labour requirements in 2010 will exceed the 2001 level in every scenario, as we can see in figure 6.9.

Figure 6.9. Integrated River Guadalquivir basin labour curve



6.4. Water consumption (m^3/ha)

Figure 6.10. Integrated River Guadalquivir basin water consumption

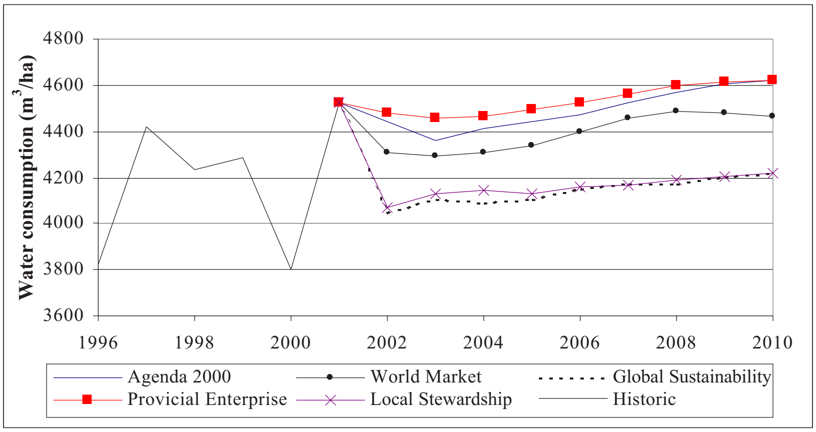
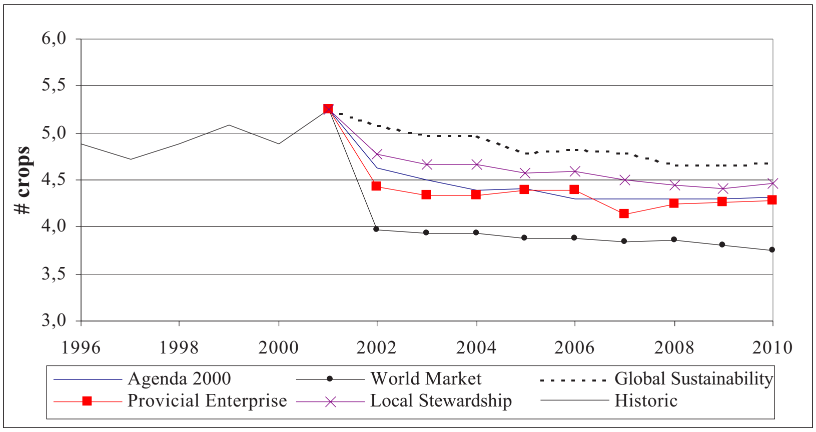


Figure 6.10 shows the water consumption of the basin, comparing the various scenarios. from this we can deduce that Scenarios 4 (Local Stewardship) and 2 (Global Sustainability) are the most economical of water, followed by Scenario 1 (World Market), 3 (Provincial Enterprise) and finally, scenario 0 (Status Quo or Agenda 2000), which is the highest water consumer.

6.5. Landscape and biodiversity

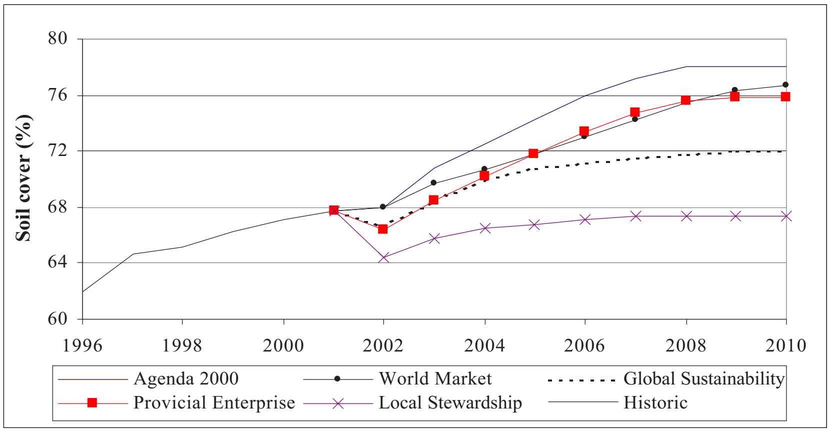
The results suggest that future cropping patterns will concentrate on a smaller number of crops. In 2001 we start with a mean of 5.3 crops at basin level, but depending on the scenario this number oscillates between 3.7 and 4.7 crops. Therefore, genetic diversity will be reduced. In the Global Sustainability scenario, this indicator reaches the highest values. In the opposite case, under the World Market scenario genetic biodiversity has the smallest value (see figure 6.11).

Figure 6.11. Integrated River Guadalquivir basin genetic biodiversity



In the same way, it should be noted that soil cover would increase in the study basin under every scenario except Local Stewardship, where the indicator remains at a similar level to that of 2001 (67.4%). This can be seen in figure 6.12, and the variations experienced in the soil cover indicator are explained by the growth in number of tree groves. This increase in soil cover would have beneficial environmental consequences such as a decrease in the risk of erosion.

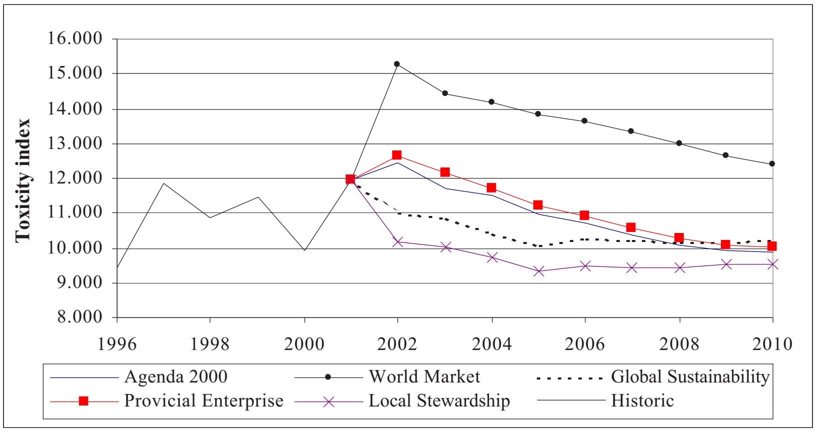
Figure 6.12. Integrated River Guadalquivir basin soil cover



6.6. Environmental impact

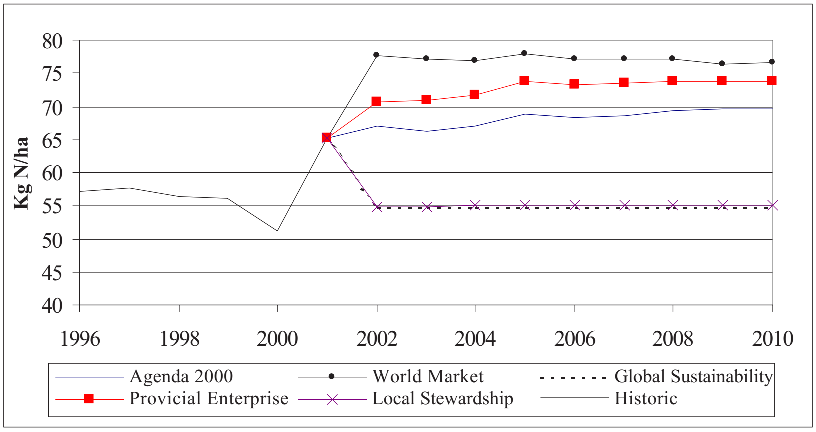
The aggregated pesticide risk indicator, based on the LD50, tends to be much larger in Scenario 1 (World Market) than in the other scenarios, where the value attained by this indicator has a very similar level in 2010. Thus, while in scenario 1 the index increases from the initial value of 11,938 to 12,405, in the remaining scenarios it falls to a lower value than in 2001, showing a very clear tendency to decrease. Local Stewardship would be the scenario where this indicator reaches its lowest value: 9,534.

Figure 6.13. Integrated River Guadalquivir basin toxicity index



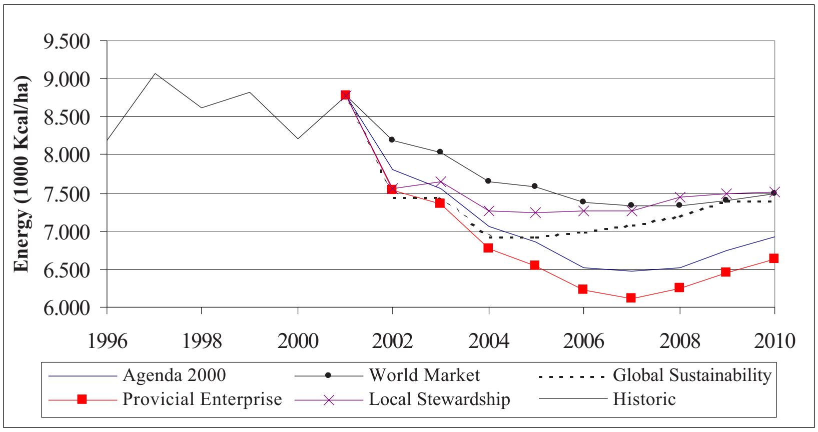
The environmental impact of the use of nitrogen is quite positive in the Global Sustainability and Local Stewardship scenarios, because the level of nitrogen use falls from 65.1 kg N/ha in 2001 to 54.9 kg N/ha in 2010. In other scenarios the negative impact of nitrogen fertilization will rise. In the case of liberalisation of agricultural markets (Scenario 1), N pollution attains its highest value: 76.7 kg N/ha.

Figure 6.14. Integrated River Guadalquivir basin nitrogen balance



We foresee that in 2010, energy balance will be less in each scenario than in 2001, when the level of this indicator was 8,767,000 kcal/ha. Comparing scenarios, the energy balance value is highest under the Local Stewardship scenario, followed by World Market, Global Sustainability, Status Quo and, finally, Provincial Enterprise.

Figure 6.15. Integrated River Guadalquivir basin energy balance



7. CONCLUSIONS

We can derive two sets of conclusions from this approach: the first centres on analysis of scenarios and the second on the application of water pricing policy under the current scenario (Agenda 2000). With regard to the first set of conclusions, this research is innovative in that it attempts to apply scenario analysis to irrigated agriculture and specifically analyses the potential development of a set of socio-economic and environmental indicators for agriculture, as consequence of changes in European policy. We tested the present 'business as usual' or 'status quo' scenario against four alternative scenarios consistent with both Water Policy and CAP: World Market, Global Sustainability, Provincial Enterprise and Local Stewardship. The alternative scenarios are defined by conditions under which, according to the Water Framework Directive (WFD), a higher water price and a particular CAP scenario would lead to changes in agrochemical use, labour costs, public-sector support via direct subsidies, output prices, etc. We believe that this case study illustrates the links between environmental policy and agricultural policy, focusing on potential tendencies in CAP policy and WFD instruments.

The results of the study under these alternative scenarios would have quite different effects on irrigation. For example, Global Sustainability seems to be the scenario that produces most beneficial values because almost every indicator moves in a positive direction simultaneously: improvement in socio-economic indicators, water saving, less pollution due to pesticides and nitrogen and finally, smaller decreases in energy exports and biodiversity than other scenarios. This scenario would mean progress according to an socio-economic and environmental point of view, although economic growth is not as fast as under other scenarios (slower growth of groves, compensated for by a greater growth in vegetable area). The remaining scenarios seem to have fewer advantages. For example, Provincial Enterprise shows quite similar results to Global Sustainability, except in the results that refer to pollution produced by nitrogen, and water saving; in the Local Stewardship scenario, farm incomes would fall and soil cover will be less than in other scenarios. World Markets seems to be the least convenient scenario from every point of view.

Figure 6.16. Summary of impact of the different on indicators for the whole River Guadalquivir basin

INDICATOR	SCENARIO				
	Agenda 2000	**World Market**	**Global Sustainability**	**Provincial Enterprise**	**Local Stewardship**
Socio-Economic indicators					
Farm Income	☺	☹	☺	☺	☹
Contribution to GDP	☺	😐	☺	☺	😐
Direct payments	☺	☺	☺	☺	☺
Employment	☺	☺	☺	☺	☺
Environmental indicators					
Water consumption	😐	☹	☺	☹	☺
Genetic diversity	☹	☹	☹	☹	☹
Soil cover	☺	☺	☺	☺	😐
Toxicity Index	☺	☹	☺	☺	☺
Nitrogen balance	☹	☹	☺	☹	☺
Energy balance	☹	☹	☹	☹	☹

Impact meaning: ☺ Positive, 😐 Neutral, ☹ Negative

All the scenario share some common features:

- A positive impact derived from reduced dependence on subsidies from CAP (null in scenario 1),
- A tendency to specialization in fruit tree and olive groves. This implies less genetic diversity and more soil cover. In the future, therefore it may be necessary to control these crops to avoid a fall in prices. But this effect is difficult to quantify because in past few years, the fruit and olive oil markets have absorbed the increased production of new plantations in the basin without a serious decrease in prices.

As far as the second set of conclusions is concerned, i.e. those that refer to the impact of the implementation of water pricing in extensive agricultural systems under Agenda 2000, we obtained two water demand functions at basin scale, one in the short and one in the long term (2001, when our data were obtained, and 2010). Both curves show an initial inelastic segment that was longer in the 2010 function, largely because of the bigger proportion of groves.

However, not all crops respond in the same way to a water tariff. Olives and some fruit groves (peaches) are stable and show an inelastic water demand curve, contributing to the inelasticity of the global water demand function in the basin. In this case, water pricing could be a good tool for attaining environmental and budgetary objectives (such as Cost Recovery), although it is unlikely that it would be an incentive for farmers reduce either water use or pollution. The annual crops belonging to the General Irrigation System tend to exhibit a higher degree of flexibility to water pricing. Some of them (e.g. vegetables) are both flexible and profitable. A water tariff could therefore be charged on the system and would give a reasonable result, without risking the survival of the system.

Rice is a rigid but fragile system (inelastic water demand), because increasing water price will not be effective up to the threshold at which farming is abandoned.

Finally, from the methodological point of view we have developed an integration of both Multicriteria and Multiperiod programming. On a very long-term time-scale, the study could have been done with static programming (much simpler), because the crop mix will tend to be stable. But our horizon (2010) is not sufficient far ahead for olive groves to become stabilized. We should also note that problems of aggregation could be satisfactorily dealt with by previous categorization of farming types.

7

The case of the River Duero Basin (Northern Spain)

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1. Case Study

The Duero Valley basin is shared by Spain and Portugal. The case study analysed here considers only the Spanish part that occupies most of the basin (almost 78,000 km^2). Within this area 555,582 hectares are used for irrigated agriculture, which consumes an average of about 3,500 hm^3 of water annually (about 6,300 m^3/ha·year). In fact, irrigation is the most important use of water in this basin, consuming 93% of the total available resources. The rest of the water is used for urban (6% of total resources availability) and industrial purposes (1%). This preponderance of irrigation suggests that the greatest potential for improving resource allocation at basin level lies in water pricing for the agricultural sector.

The climate in this region may be defined as continental, with long cold winters and short hot summers. As rain falls mainly in the autumn and winter, water is a limiting factor in the warm and hot summer season, and irrigation is required to raise productivity. In any case, crops cultivated in this area are mainly low-value-added and dependent on CAP subsidies. In an typical year (i.e. without water restrictions) the crop distribution in the area under study is as follows: maize (30%), winter cereals (25%), sugar beet (15%), alfalfa (10%), sunflower (5%) and other minor crops.

Like most irrigated districts in Spain, water pricing in the area discussed here is currently based on a fixed sum per unit of irrigated area. The average water tariff is about 62 €/ha, equivalent to a volumetric tariff of 0.01 €/m^3. This amount, which is collected by the State, is well below the estimated cost of supply, but the farmers' payments resemble a licence fee related to farm area rather than to water abstraction and use.

Irrigation in the Duero Valley, as established by Spanish legislation, is divided into irrigated areas, internally managed by more than 100 water user associations known as "Comunidades de Regantes" (CRs). For this research project, given the practical impossibility of considering all of them, we selected seven representative CRs at basin level, covering 51,343 irrigated hectares (9.2% of the total irrigation in the Duero). Table 7.1 shows the basic features of each CR.

We surveyed 367 farmers from these seven irrigated areas (an average of 52 producers per area) in order to gather the information we needed to develop the cluster technique to generate homogeneous groups and subsequently feed the models (technical coefficients for the objective functions and constraints).

Table 7.1. General features of the seven irrigated areas analysed

Features	CR Canales Bajo Carrión	CR Canal Margen Izda. del Porma	CR Canal General del Páramo	CR Canal del Pisuerga	CR Canal de San José	CR de la Presa de la Vega de Abajo	CR Virgen del Aviso
Province	Palencia	León	León	Palencia / Burgos	Zamora / Valladolid	León	Zamora
Altitude (m a.s.l.)	775 – 825	750 – 830	800	760 – 830	645	800	645
Average rainfall	527 – 448	732	498	427	364	498	364
Irrigated surface (ha)	6,588	12,386	15,554	9,392	4,150	1,403	1,870
Num. of landowners	899	3,500	5,950	2,715	1,406	1,500	820
Num. of farmers	137	251	488	223	166	82	118
Average irrigated farm area (ha)	48.0	49.4	31.9	42.2	25.0	17.1	15.8
Water allotment (m^3/ha·year)	5,950	6,250	6,587	8,100	8,192	6,105	8,021
Irrigation system	Surface irrigation and sprinklers only for sugar-beet	Surface irrigation and sprinklers only for sugar-beet	Surface irrigation and sprinklers only for sugar-beet and beans	Surface irrigation and sprinklers only for sugar-beet and alfalfa	Surface irrigation and sprinklers only for sugar-beet and alfalfa	Surface irrigation and sprinklers only for sugar-beet	Surface irrigation and sprinklers only for sugar-beet
Water tariff paid (€/ha·year)	40.06	66.10	85.34	60.59	85.94	36.06	Variable
Age of irrigation system	30 years	20 years	50 years	30 years	40 years	40 years	40 years
Irrigation system efficiency	65% in surface irrigation and 70% in sprinkler irrigation	75% in surface irrigation and 80% in sprinkler irrigation	65% in surface irrigation and 70% in sprinkler irrigation	60% in surface irrigation and 65% in sprinkler irrigation	65% in surface irrigation and 70% in sprinkler irrigation	65% in surface irrigation and 70% in sprinkler irrigation	60% in surface irrigation and 65% in sprinkler irrigation
Number of interviews	52	54	61	32	68	34	66
Number of clusters	4	4	2	3	3	3	3

Once the cluster technique had been applied in each CR, a total of 22 different homogeneous groups were defined. Table 7.2 shows the basic features of each of them.

Table 7.2. Main features of farmer-types

Irrigated area	N.	Name	% / no. farmers	%/ total surface	Main crops	Weights		
						w_{TGM}	w_{VAR}	w_{TL}
CR Canales Bajo Carrión	11	Part-time farmers	22.9%	17.8%	Maize, winter cereal and sugar-beet	0.724	0.276	0.000
	12	Livestock Farmers	21.3%	24.2%	Maize, alfalfa and winter cereal	0.465	0.535	0.000
	13	Small commercial farmers	27.8%	8.9%	Maize, alfalfa and winter cereal	1.000	0.000	0.000
	14	Risk-averse farmers	27.8%	49.2%	Winter cereal and maize	0.671	0.329	0.000
CR Canal Margen Izda. del Porma	21	Large-scale commercial farmers	40.7%	45.8%	Maize	1.000	0.000	0.000
	22	Part-time farmers	5.6%	5.4%	Winter cereal and maize	0.302	0.698	0.000
	23	Risk-averse farmers	16.7%	16.6%	Winter cereal, Maize and sunflowers	0.479	0.521	0.000
	24	Livestock farmers	37.0%	32.1%	Maize and alfalfa	0.852	0.148	0.000
CR Canal del Páramo	31	Risk-neutral farmers	72.0%	69.6%	Maize, sugar-beet and beans	1.000	0.000	0.000
	32	Risk diversification farmers	28.0%	30.4%	Maize, winter cereal and sugar-beet	0.785	0.215	0.000
CR Canal del Pisuerga	41	Conservative farmers	20.6%	12.5%	Winter cereal and alfalfa	0.000	1.000	0.000
	42	Large-scale commercial farmers	35.3%	57.5%	Winter cereal, sugar-beet and maize	0.425	0.575	0.000
	43	Livestock farmers	44.1%	38.2%	Alfalfa, winter cereal, sugar-beet and maize	0.623	0.377	0.000
CR Canal de San José	51	Risk diversification farmers	35.3%	39.6%	Maize, winter cereal and alfalfa	0.544	0.456	0.000
	52	Young commercial farmers	35.3%	40.3%	Maize and sugar-beet	0.955	0.045	0.000
	53	Maize growers	29.4%	20.1%	Maize	1.000	0.000	0.000
CR Presa de la Vega de Abajo	61	Small-scale elderly farmers	20.6%	11.5%	Maize and winter cereal	0.967	0.033	0.000
	62	Sugar-beet growers	29.4%	31.4%	Maize and sugar-beet	1.000	0.000	0.000
	63	Young commercial farmers	50.0%	57.1%	Maize, sugar-beet and winter cereal	1.000	0.000	0.000
CR Virgen del Aviso	71	Commercial farmers	45.5%	23.2%	Maize, sugar-beet and winter cereal	1.000	0.000	0.000
	72	Risk diversification farmers	24.2%	33.4%	Maize, winter cereal and sugar-beet	0.448	0.552	0.000
	73	Conservative farmers	30.3%	43.4%	Winter cereal, sun-flowers and maize	0.197	0.803	0.000

A multicriteria methodology was applied to each cluster in order to calculate the different weighting vectors. The results are also shown in table 7.2. It is worth noting that there are important differences among the relative weights considered by the different groups (farmer types), demonstrating the existence of large disparities in the shape of the multi-attribute utility functions (MAUF) that each group tried to optimise (i.e. differences in behaviour).

2. METHODOLOGY

In order to simulate different policy scenarios it is necessary to build models that allow us to simulate farmers' decision-making in the long term in each case (farmer-types). These simulations are carried out considering static long-term models that enable future impacts that could generate feasible changes in the decision variables and policy-makers' attributes (indicators) of each scenario to be measured.

The long-term models developed take the MAUFs obtained in each case as ***objective functions*** (see table 7.2). Thus, each individual group of farmers considered has its own utility function, which the producers within each cluster try to maximize in any scenario they face, e.g. agricultural and water policies frameworks.

These MAUFs are a way of condensing the way in which farmers keep in mind their various objectives in order to take decisions. In this sense it worth noting that the particular objectives considered within the different MAUFs are:

- *Maximisation of total gross margin* (TGM).
- *Minimisation of risk*, measured as the variance of the TGM (VAR).
- *Minimisation of total labour input* (TL).

For simulations, the ***decision variables*** to be included in the models should consider any means by which farmers adapt to different policy scenarios. Possible ways of dealing with modifications in the institutional framework considered in this study include:

- Changes in crop plans, considering irrigated and rain-fed crops.
- Changes in irrigation technology, considering the substitution of surface irrigation by sprinklers whenever it is possible.
- Changes in the way of cultivating lands. "Conventional tillage" is not the only way of cultivating crops; the possibility of "minimum tillage" and "direct sowing" techniques would be also available.

Bearing these possibilities in mind, we developed the decision variables in the long-term models as combinations of crops with different irrigation technique systems and tillage alternatives, as is shown in the following table:

Table 7.3. Combinations of decision variables

Crop	Irrigated / Rain-fed	Irrigation system	Tillage system
Wheat			
Barley			
Maize			Conventional tillage
Sugar-beet	Irrigated	Surface	
Alfalfa			Minimum Tillage
Potato	Rain-fed	Sprinklers	
Beans			Direct Sowing
Sunflower			
Set-aside			

Nevertheless, in spite of the possibilities considered *a priori* as combinations of the columns of the previous table, it should be noted that not all such combinations would be feasible from an agronomic point of view. In fact, 47 differentiated activities were considered in the different models.

Finally, it should be noticed that the ***constraints*** considered for each of the scenarios analysed were the following:

- *Land constraint*. The sum of all crops must be equal to the total surface available to the farm type of each cluster.

- *CAP constraints*. We included 5% set-aside for cereal, oilseed and protein crop (COPs). Sugar-beet, because of the quota, is limited in each cluster to the maximum hectareage in the period studied.
- *Rotational constraints*. These were taken into account according to the criteria revealed for the farmers in the survey.
- *Market constraints*. We decided to limit alfalfa hectareage to the maximum in the period 1993-97 because of its rigid demand. This crop is exclusively consumed by dairy cows and sheep, whose flock sizes are fairly constant, due to CAP quotas, making it unlikely that more alfalfa could be sold than the maximum proposed.

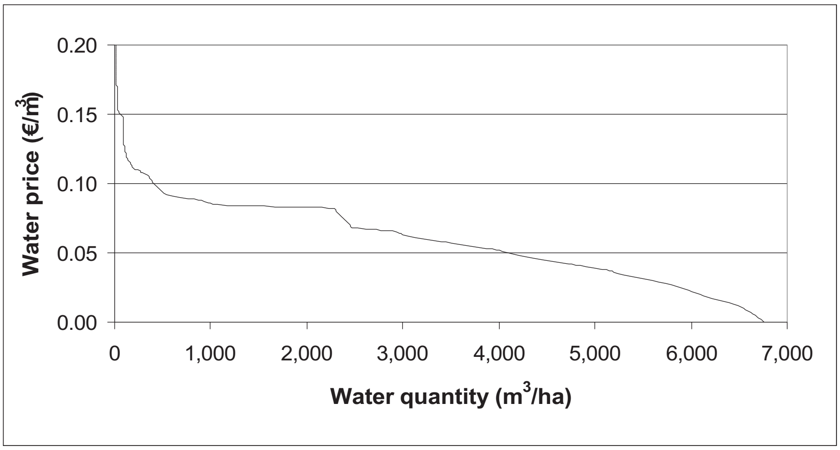
3. WATER PRICING IMPACT. RESULTS FOR THE *"STATUS QUO"* SCENARIO (AGENDA 2000)

The simulation carried out in the long term considering a framework characterized by the maintenance of the "*status quo*" in the agricultural policy has provided results for each of the seven irrigated area analysed. Nevertheless, the huge amount of data generated by these particular analyses can be summarized by integrating all results at basin level for the whole Duero Valley. Furthermore, these aggregated results are the most important ones for policy decision-making. This is why in this section describes only these integrated results. In any case, particular data for the different irrigated areas and "farmer types" considered can be obtained on request to the authors.

3.1. Water demand

The simulations carried out for the "*status quo*" scenario, enabled the demand curves of irrigation water to be obtained for the different CRs and groups of farmers considered. Aggregating these particular results allowed us to estimate the demand curve for the Duero Basin as a whole (figure 7.1).

Figure 7.1. Water demand in the Duero Valley



Spanish irrigation water users currently pay the State a price determined by irrigated area that only partially reflects the cost of providing water. In fact, only the operational and management costs are covered by this tariff. The remaining financial costs (i.e. capital depreciation) are met by the national budget and are a hidden subsidy to users, especially for the agricultural sector.

The first practical problem that we encountered in establishing appropriate scenarios for water pricing is the lack of information regarding the real cost of irrigation water that should be used to implement the WFD. As far as Spain is concerned, only few studies have been carried out, and these have produced results ranging from 0.02 to 0.11 €/m^3. In addition to the difficulty of setting up reliable cost estimates for irrigation in practice, this wide range of costs is due to the different levels of analysis (basin, smaller hydrological system or a single irrigated area) used for this purpose and the kind of costs considered. We therefore selected three water-pricing scenarios for our case study:

- *'Subsidized'* price. This considers a price of 0.02 €/m^3. This price will not be capable, in our opinion, of recovering total costs, but might at least serve as an economic instrument to encourage more efficient resource use.
- *'Medium' price*. A price of 0.04 €/m^3 might be regarded as a 'fair' value for cost recovery, that would at least cover the financial costs.
- *'FCR' price*. A price of 0.06 €/m^3 would be a tough application of full-cost-recovery principle, including a provision for environmental costs.

Analysing the demand curve for the whole Duero basin in this "*status quo*" scenario, it can be seen how irrigation water consumption varies for the interval of prices proposed above as possible future scenarios of water pricing (table 7.4):

Table 7.4. Decrease in the consumption of irrigation water in the Duero basin*

	Water price		
	'Subsidized' price 0.02 €/m^3	**'Medium' price 0.04 €/m^3**	**'FCR' price 0.06 €/m^3**
Consumption (m^3/ha)	-665	-1,844	-3,534
(Current consump. = 6,759)	(-9.8%)	(-27.3%)	(-52.3%)

* The percentages resulting in the decrease of the indicators vis-à-vis the current situation are shown in parentheses.
Source: Authors' own analysis

As the above table shows, the application of a 'FCR' price would produce considerable important savings in the consumption of water for irrigation (over 50%). On the other hand, implementation of the other tariffs would produce smaller water savings, but such reductions in water consumption could still be regarded as useful. In fact, 'subsidized' price and 'medium' price will generate decreases of 10% and 27% in current consumption respectively. This confirms that water pricing is a very effective economic instrument to reduce water use in these extensive (low profitability) agricultural systems.

In the analysis of the effectiveness of this economic instrument to decrease the consumption of water in irrigable agriculture is necessary to highlight the influence of the slope (elasticity) of the demand curve. In this way we can see how in the most elastic segments in the curve (shallower slope) an increment in water price involves greater savings in the quantity of water consumed. This is because of these price ranges an increment of water price causes a relatively important change in farmers' decision variables vector (crop plan and irrigation technology).On the other hand, in the most inelastic segments (steeper slope) an rise in the water tariff does not produce important savings, since the increase in the price does not involve changes in the farmers' decision variable vectors.

The changes experienced by an average farmer in the Duero Basin in his/her decision variables under this scenario framework facing the water price under consideration can be observed in the following table:

Table 7.5. Changes in the decision variables for an average farmer in the Duero Basin (% total area)

Crop - irrigation technology*	Water price		
	'Subsidised' price 0.02 €/m^3	**'Medium' price 0.04 €/m^3**	**'FCR' price 0.06 €/m^3**
Winter cereals-Furrow	4.36	2.82	1.48
Winter cereals-Sprinklers	0.12	0.12	0.12
Winter cereals-Rain-fed	9.06	21.54	31.54
Maize-Furrow	32.45	29.87	22.42
Maize-Sprinklers	10.05	6.24	1.86
Sugar-beet-Sprinklers	9.06	7.13	3.83
Sunflower-Furrow	0.00	0.00	0.00
Sunflower-Sprinklers	0.03	0.03	0.03
Sunflower-Rain-fed	5.92	5.51	4.25
Bean-Furrow	0.00	0.00	0.00
Bean-Sprinklers	0.00	0.00	0.00
Potato-Furrow	0.00	0.00	0.00
Potato-Sprinklers	0.00	0.00	0.00
Alfalfa-Furrow	2.39	0.34	0.05
Alfalfa-Sprinklers	0.09	0.09	0.09
Alfalfa-Rain-fed	18.83	16.69	19.17
Set-a-side	7.64	9.63	15.17

Source: Authors' own analysis
* In order to simplify the analysis we do not list the tillage systems used for each crop

We can thus see that, as the water tariff increases, farmers will progressively abandon those crops with the greatest water requirements (maize, sugar-beet and alfalfa), increasing the area devoted to rain-fed crops (winter cereals and alfalfa).I It can also be appreciated how water pricing does not increase the adoption of new irrigation technologies in this scenario, since the percentage of cultivated area with sprinkler irrigation technology remains stable or even diminishes. This is because the low profitability of these agricultural systems means that farmers cannot afford to invest more money in irrigation infrastructure.

3.2. Economic impact

The changes in the economic indicators proposed (gross margin -TGM, contribution to GDP - GDPCON, public support -SUBSID and public revenue due to water tariffs -PUBCOL) motivated by the implementation of the WFD and obtained by the different pricing levels can be seen observed in the following figure for the "*status quo*" scenario.

The implementation of water tariffs is likely to bring about an important loss in farmers' gross margins (TGM). This is due to three possible causes: the payment to the public body in charge of the tariffs, the abandonment of those activities that generate higher added value (crops such as maize, sugar-beet and alfalfa) and the adoption of new irrigation technologies that add to the variable costs associated with agricultural activities. The final effect on TGM can be observed in figure 7.2 and table 7.6, in which only the feasible prices of water discussed above are considered.

Figure 7.2. Economic indicators in the Duero Valley

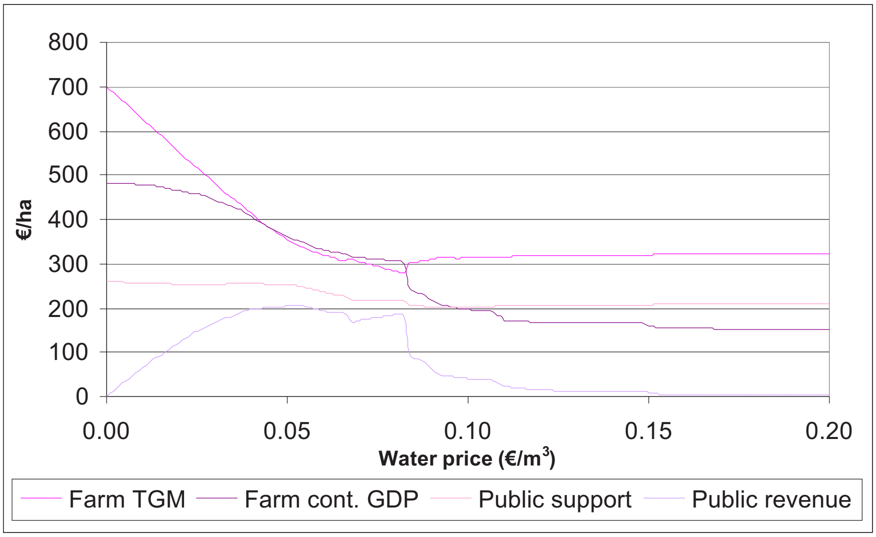


*Table 7.6. Changes in the economic indicators for the whole Duero basin (€/ha·year)**

Economic indicators (€/ha)	Water price		
	'Subsidized' price 0.02 €/m^3	'Medium' price 0.04 €/m^3	'FCR' price 0.06 €/m^3
TGM (Current TGM = 701)	-148.67 (-21.22%)	-286.93 (-40.96%)	-380.30 (-54.28%)
GDPCON (Current GDPCON = 483)	-15.83 (-3.69%)	-74.73 (-15.49 %)	-151.10 (-31.31%)
SUBSID (Current SUBSID = 260)	-5.68 (-2.19%)	-4.54 (-1.75%)	-24.09 (-9.27%)
PUBCOL (Current PUBCOL = 0)	121.87 (100%)	196.59 (100%)	193.48 (100%)

* The percentages resulting in the decrease of the indicators vis-à-vis the current situation are shown in parentheses.
Source: Authors' own analysis

This decrease in the profitability of irrigated agriculture might lead to the economic unsustainability of farms, which in turn might bring about the withdrawal of an important percentage of farmers from agriculture in these kinds of irrigated systems.

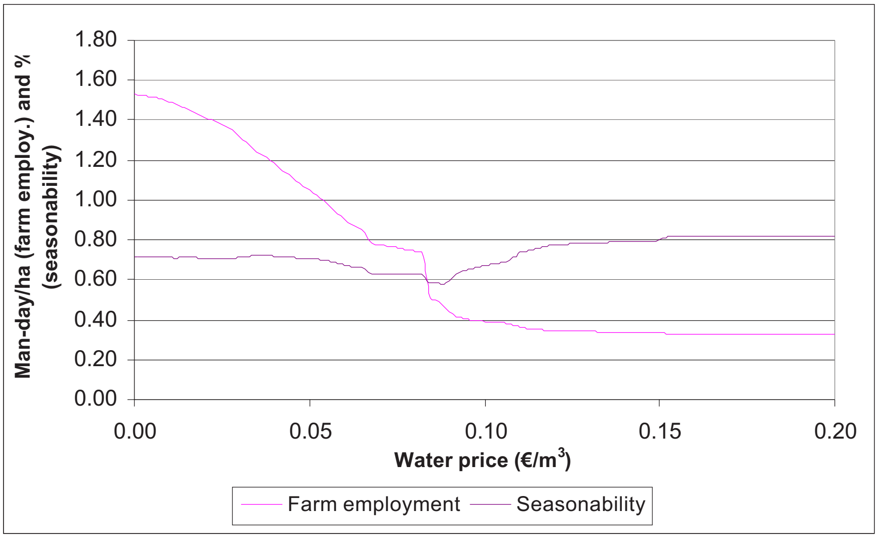
The loss in TGM is also accompanied by a decrease in the contribution of agriculture to the GDP (GDPCON) indicator and a decrease in the subsidies (SUBSID) received by farmers and paid by the public sector.

Finally, we must point out that the amount of money collected by the state through water tariffs (PUBCOL) increases as these rise from 0.00 to 0.05 €/m^3, where the maximum revenue obtained by the state is reached. Beyond this tariff, PUBCOL begins to decrease. We take into account that the application of a 'FCR' price will induce a decrease in the quantity of water used by irrigation. In a way the volume of available water for other social uses (urban, industrial, leisure, etc) would increase. In that respect, with the aim of recovering all the costs of providing water services, the final users of water resources should pay the appropriate volumetric tariff. This would make water pricing an efficient way to allocate water resources in the Duero Valley. Otherwise, if users were unwilling to pay the appropriate tariff, the 'FCR' price would not achieve its aim. In this case, water pricing causes economic inefficiency that should be borne by taxpayers via budgetary transfers.

3.3. Social impact

Besides a reduction in water consumption, a rise in the price of water would lead to a decrease in the employment directly generated by the agricultural sector (EMPLOY) and an insignificant decrease in seasonal labour employment (SEASONA), as the following figure shows.

Figure 7.3. Social indicators in the Duero Valley



For the Duero basin, as shown in the previous figure and in table 7.7, the implementation of water pricing would involve a fairly serious decrease in the direct employment generated by the agricultural sector (more than 40% for the 'FCR' price). This decrease in agricultural employment is a social impact caused by substitution of the most water-intensive crops, which also tend to be the most labour-intensive, by others with reduced water and labour requirements. This could potentially have a serious social impact on the area studied. However, this drop in demand for labour should not be dramatized, because farms in this study area are mainly family operations, with only a few hired personnel. Thus, this drop in demand for labour would be translated primarily into an increase in farmers' leisure. Nevertheless, it is worth considering the risk represented by the drop experienced by this indicator and the TGM in the long term. In this way, both policies (water pricing and CAP) could increase the structural change observed in the Duero Basin in recent years (larger farms with fewer farmers).

Table 7.7. Changes in the social indicators for the whole Duero basin*

Social indicators	**Water price**		
	'Subsidized' price 0.02 €/m³	**'Medium' price 0.04 €/m³**	**'FCR' price 0.06 €/m³**
EMPLOY (man-day/ha) (Current EMPLOY = 1.53)	-0.12 (-7.68%)	-0.34 (-22.50%)	-0.63 (-40.96%)
SEASONA (%) (Current SEASONA = 71%)	(-0.43%)	(0.58%)	(-3.91%)

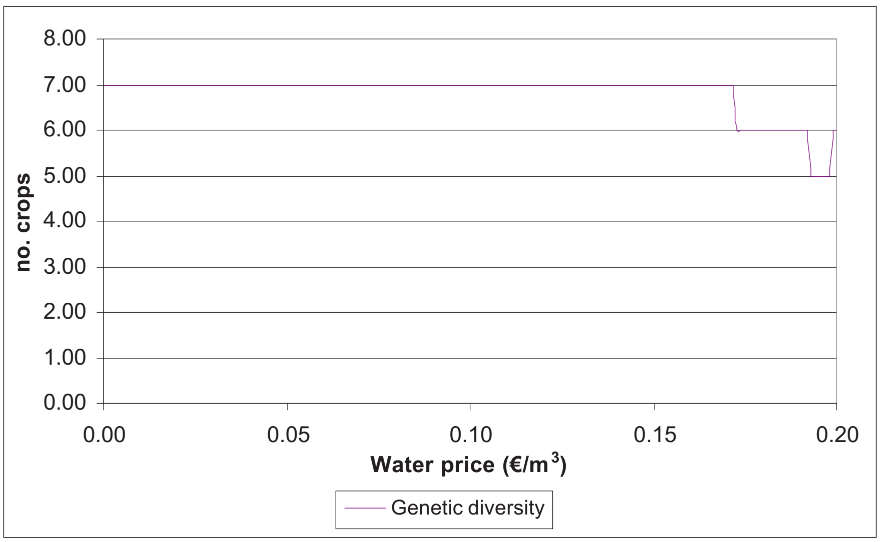
* The percentages resulting in the decrease of the indicators vis-à-vis the current situation are shown in parentheses.
Source: Authors' own analysis

Regarding the seasonal demand for agricultural labour, figure 7.3 and table 7.7 also show how increasing irrigation water tariffs have only slight effects on the variation of the SEASONA indicator. This suggests that this economic instrument has little impact on the annual distribution of labour and thus on the size of the rural population.

3.4. Landscape and biodiversity

With respect to the impact of water pricing on agricultural genetic biodiversity (DIVERS) observed for the whole Duero basin (see figure 7.4), it is worth emphasising that this indicator remains stable for the range of prices regarded as feasible in the future.

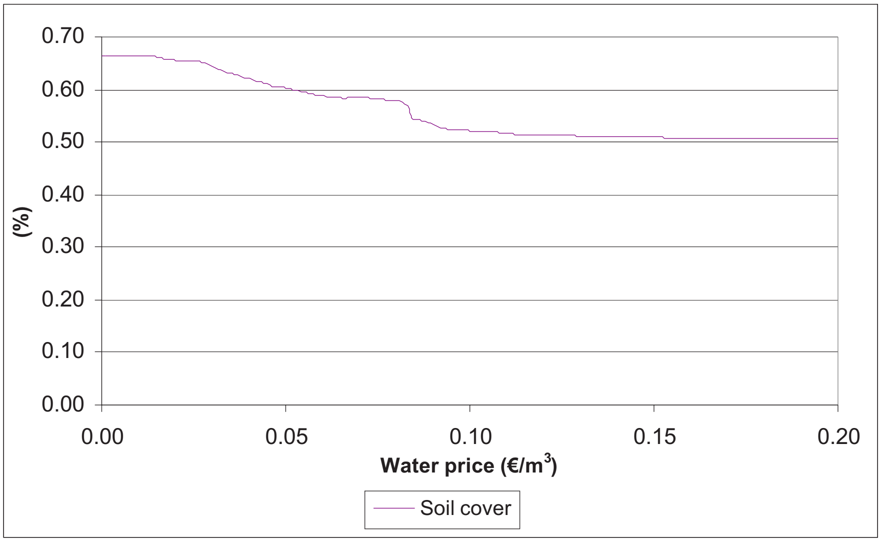
Figure 7.4. Genetic diversity in the Duero Valley



In the same way, as a consequence of the implementation of volumetric irrigation water tariffs, it should be noted that soil cover (SOILCOV) would lessen in the study areas shown in figure 7.5.

The variations experienced in the soil cover indicator have their explanation in the change of crops that would take place because of water pricing. Thus, the preference for crops with smaller water requirements, normally with shorter life cycle (less days on the land), would involve a reduction in this indicator. This decrease in SOILCOV would have serious environmental consequences such as an increase in the risk of soil erosion. In the long run, however, we need to improve the precision of these results. In this way the adoption of new tillage systems more respectful of the environment (minimum tillage and direct sowing) could reduce the potential risk of soil erosion.

Figure 7.5. Soil cover in the Duero Valley



Such circumstances can be observed for this "*status quo*" scenario in table 7.8, for the range of prices of water analysed. It can be noticed that although the water pricing instrument will not involve a decrease in the number of crops in the study area, the change of crops will indeed produce a decrease in the percentage of soil cover.

Table 7.8. Changes in the environmental indicators for the whole Duero basin (I)*

Environmental indicators	Water price		
	'Subsidized' price 0.02 €/m^3	**'Medium' price 0.04 €/m^3**	**'FCR' price 0.06 €/m^3**
DIVERS (no. of crops) (Current DIVERS = 7)	(0.00%)	(0.00%)	(0.00%)
SOILCOV (%) (Current SOILCOV = 66%)	(-0.95%)	(-4.44%)	(-7.68%)

* The percentages resulting in the decrease of the indicators vis-à-vis the current situation are shown in parentheses.
Source: Authors' own analysis

3.5. Environmental impact

The introduction of irrigation water pricing would also affect other environmental indicators such as nitrogen (BALNIT) and energy (BALENE) balances and pesticides risk (PESTRISK). This is due to the relationship between current crop plans and the demand for nitrogen fertilizers, energy and pesticides. It is thus necessary to observe that certain crops such as maize or sugar-beet (with high water requirements) have higher requirements for these inputs than others with lower irrigation needs, such as irrigated winter cereals, and much more than rain-fed crops. Changes in crop plans produced by water pricing would thus decrease the consumption of agrochemicals, i.e. nitrogen fertilizers or pesticides, and energy.

These relations can be observed in the figure 7.6 for the whole Duero basin.

The conclusion obtained from these results is that irrigation water pricing would have a positive impact on non-point source pollution produced by the irrigated agricultural sector. In fact, the amount of agrochemicals (fertilizers and pesticides) run-off would be reduced, decreasing the amount of nitrogen and toxic products released into the environment. This is due to the relationship, commented on above, between crop mixes and fertilizer and pesticide use. Thus, as farmers substitute crops in order to save water, nitrogen fertilizer and pesticide use will also directly decrease, improving BALNIT and PESTRISK indicators.

This is shown in table 7.9 for each water price scenario considered:

Figure 7.6. Environmental indicators in the Duero Valley

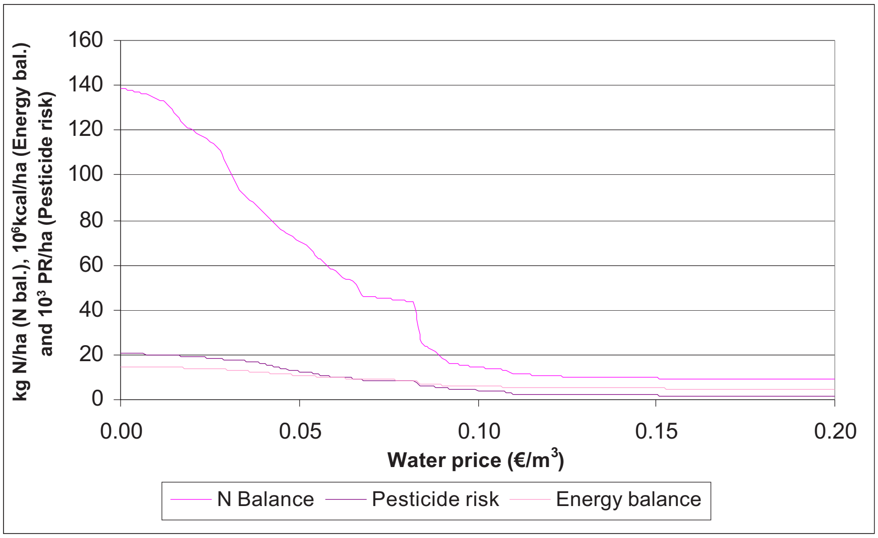


Table 7.9. Changes in the environmental indicators for the whole Duero basin (II)*

Environmental Indicators	Water price		
	'Subsidized' price 0.02 €/m^3	**'Medium' price 0.04 €/m^3**	**'FCR' price 0.06 €/m^3**
BALNIT (kg N/ha) (Current BALNIT = 138)	-18.57 (-13.41%)	-54.76 (-39.55%)	-81.34 (-58.75%)
BALENE (10^6 kcal/ha) (BALENE current = 15)	-0.87 (-5.87%)	-2.77 (-18.60%)	-5.13 (-34.43%)
PESTRISK (10^3 PR/ha) (Current PESTRISK = 21)	-1.40 (-6.83%)	-4.60 (-22.40%)	-10.42 (-50.71%)

* The percentages resulting in the decrease of the indicators vis-à-vis the current situation are shown in parentheses.
Source: Authors' own analysis

On the other hand, energy balance also decreases as a result of water pricing (see figure 7.6 and table 7.9). This is because irrigated crops are more energy-efficient than rain-fed ones. In fact, due to their occupancy of land during the summer, irrigated crops are able to fix much more solar energy than rain-fed crops (established only in winter and spring seasons). Thus, from an energy point of view, the environmental impact of water pricing is negative, since it would worsen the generation of greenhouse gases.

3.6. Summary

In order to summarize all the information above about socio-economic and environmental impacts of water pricing, the following table shows the evolution of the various indicators proposed for the case study analysed.

Table 7.10. Impact of water pricing on the indicators for the whole Duero basin

INDICATOR	Water price		
	'Subsidized' price 0.02 €/m³	**'Medium' price 0.04 €/m³**	**'FCR' price 0.06 €/m³**
Consumption (m^3/ha)	☺	👍	👍
		Economic indicators	
TGM (€/m^3)	☹	👎	👎
GDPCON (€/m^3)	☹	👎	👎
SUBSID (€/m^3)	😐	😐	☺
PUBCOL (€/m^3)	☺	☺	☺
		Social indicators	
EMPLOY (man-day/ha)	☹	👎	👎
SEASONA (%)	😐	😐	😐
		Environmental indicators	
DIVERS (no. of crops)	😐	😐	😐
SOILCOV (%)	😐	☹	☹
BALNIT (kg N/ha)	☺	👍	👍
BALENE (10^6 kcal/ha)	😐	☹	☹
PESTRISK (10^3 PR/ha)	☺	👍	👍

Impact meaning: 👍 Very positive, ☺ Positive, 😐 Neutral, ☹ Negative, 👎 Very negative.

4. RESULTS. WATER DEMAND AND OTHER INDICATORS BY SCENARIOS

The long-term results for the different scenarios can be considered all together as an interval of confidence within which any real future of the agricultural sector in the Duero Valley will be located. This is why the analysis of the different indicators previously defined for all scenarios at the same time is really useful. Thus, in the following sections we discuss each indicator individually, considering only the feasible range of water prices mentioned above.

4.1. Water demand

Table 7.11 shows the consumption of water for irrigation and the water savings estimated for each policy scenario and feasible water prices. The resulting figures show that the greatest savings would be obtained in the Local Stewardship scenario (except for 'FCR' price, where the World Markets scenario produces the greatest decrease in consumption). Under this scenario we could obtain of savings ranging from 19% to 59%, while the Provincial Enterprise scenario produces the least impact of water pricing on consumption, with savings of between 4% and 27%.

From these results, we can confirm that water pricing and agricultural policies are equally important factors in determining water consumption. Thus, if water saving is a political objective, both policies (water and agricultural policies) will need to be coordinated in order to meet this objective efficiently; that is, with the lowest negative social and economic impacts as possible, as we now discuss in our analysis of the various indicators proposed.

Table 7.11. Changes in the consumption of irrigation water for the whole Duero basin (m^3/ha)*

Consumption (m^3/ha)	Water price		
	'Subsidized' price 0.02 €/m^3	**'Medium' price 0.04 €/m^3**	**'FCR' price 0.06 €/m^3**
Agenda 2000 (Current CONSUMP =6.759)	-665 (-9.85%)	-1.844 (-27.28%)	-3.534 (-52.29%)
World Markets (Current CONSUMP =7.262)	-753 (-10.37%)	-2,022 (-27.84%)	-4,281 (-58.96%)
Global Sustainability (Current CONSUMP =6.874)	-805 (-11.71%)	-1,838 (-26.73%)	-2,537 (-36.90%)
Provincial Enterprise (Current CONSUMP =6.850)	-266 (-3.88%)	-942 (-13.76%)	-1.819 (-26.56%)
Local Stewardship (current CONSUMP =6.322)	-1,212 (-19.18%)	-2,074 (-32.80%)	-3,141 (-49.69%)

* * The percentages resulting in the decrease of the indicators vis-à-vis the current situation are shown in parentheses.
Source: Authors' own analysis

4.2. Economic impact

4.2.1.- *Total Gross Margin (TGM)*

The comparative results obtained for the various scenarios regarding the TGM indicator are shown in table 7.12:

Table 7.12. Changes in the TGM indicator for the whole Duero basin (€/ha·year)*

TGM (€/ha)	Water price		
	'Subsidized' price 0.02 €/m^3	**'Medium' price 0.04 €/m^3**	**'FCR' price 0.06 €/m^3**
Agenda 2000 (Current TGM =701)	-149 (-21.22%)	-287 (-40.96%)	-380 (-54.28%)
World Markets (Current TGM =446)	-162 (-36.44%)	-304 (-68.23%)	-376 (-84.28%)
Global Sustainability (Current TGM =689)	-157 (-22.82%)	-300 (-43.48%)	-405 (-58.71%)
Provincial Enterprise (Current TGM =824)	-150 (-18.19%)	-289 (-35.04%)	-408 (-49.44%)
Local Stewardship (Current TGM =530)	-151 (-28.53%)	-257 (-48.53%)	-324 (-61.02%)

* The percentages resulting in the decrease of the indicators vis-à-vis the current situation are shown in parentheses.
Source: Authors' own analysis

As might have been expected, the World Markets scenario is where water pricing has the most negative impact on farmers' income, generating reductions in the TGM from 36% ('subsidized' price) to 84% ('FCR' price).On the other hand, the Provincial Enterprise scenario produces the least decreases in TGM: 18% for 'subsidized' price and 49% for the higher tariff considered. In any case, these results should be taken into account because the losses in farmers' income would make their farming activities non-competitive, and could thus lead to their abandonment of agriculture, with the consequent social costs.

The conclusion we can obtain from these results is that irrigation water pricing always causes a considerable drop in the profitability of agricultural activities, but in this case the main variable that determines farmers' income is agricultural policy (agricultural policy scenarios analysed). Such a circumstance is probably more relevant in the Duero basin, where agricultural systems are mainly devoted to continental crops, which are highly dependent on public subsidies.

4.2.2.- *Contribution of irrigated agriculture to GDP (GDPCON)*

Table 7.13 outlines the changes in the GDPCON indicator due to the progressive implementation of water pricing for the policy scenarios analysed.

Table 7.13. Changes in the GDPCON indicator for the whole Duero basin (€/ha·year)*

GDPCON (€/ha)	Water price		
	'Subsidized' price 0.02 €/m^3	**'Medium' price 0.04 €/m^3**	**'FCR' price 0.06 €/m^3**
Agenda 2000 (Current GDPCON =483)	-18 (-3.69%)	-75 (-15.49%)	-151 (-31.31%)
World Markets (Current GDPCON =473)	-32 (-6.72%)	-93 (-19.71%)	-186 (-39.41%)
Global Sustainability (Current GDPCON =514)	-33 (-6.32%)	-100 (-19.37%)	-143 (-27.75%)
Provincial Enterprise (Current GDPCON =659)	-17 (-2.56%)	-48 (-7.34%)	-98 (-14.89%)
Local Stewardship (Current GDPCON =334)	-56 (-16.75%)	-94 (-28.00%)	-144 (-43.09%)

* The percentages resulting in the decrease of the indicators vis-à-vis the current situation are shown in parentheses.
Source: Authors' own analysis

Table 7.13 shows that the introduction of water pricing would lead to a decrease in the amount of product sold by the agricultural sector for every case. Nevertheless, the greatest reductions, in relative terms, are found in the Local Stewardship scenario (from 17% for a 'subsidized' price until 43% for a 'FCR' tariff). On the other hand, the opposite situation (least decrease in the GDPCON indicator) is associated with the Provincial Enterprise scenario, where this indicator falls between 3% and 15%.

In this sense it is important to note that this indicator is also much more dependent on the policy framework than on the tariffs implemented.

4.2.3.- *Public subsidies (SUBSID)*

The evolution of the subsidies indicator is also analysed in table 7.14.

It is worth remembering that subsidies increases as the water price rises, except under the "*status quo*" scenario. Likewise, it can be seen that water pricing only slightly changes the amount of money received by farmers (the maximum variation is -9% for the "*status quo*" scenario and 'FCR' price).

In any case, this indicator is mainly based on the policy scenario considered rather than on the price of water.

*Table 7.14. Changes in the SUBSID indicator for the whole Duero basin (€/ha·year)**

SUBSID (€/ha)	Water price		
	'Subsidized' price 0.02 €/m^3	'Medium' price 0.04 €/m^3	'FCR' price 0.06 €/m^3
Agenda 2000 (Current SUBSID =260)	-6 (-2.19%)	-5 (-1.75%)	-24 (-9.27%)
World Markets (Current SUBSID =0)	0 (100.00%)	0 (100.00%)	0 (100.00%)
Global Sustainability (Current SUBSID =217)	3 (1.41%)	7 (3.40%)	6 (2.82%)
Provincial Enterprise (Current SUBSID =227)	-0.23 (-0.10%)	2 (0.80%)	2 (0.82%)
Local Stewardship (Current SUBSID =235)	5 (2.23%)	6 (2.46%)	12 (4.91%)

* The percentages resulting in the decrease of the indicators vis-à-vis the current situation are shown in parentheses.
Source: Authors' own analysis

4.2.4.- *State collection of water tariff (PUBCOL)*

When feasible water tariffs are analysed for the various policy scenarios considered, the results regarding public collection of water tariffs are shown in table 7.15.

*Table 7.15. Changes in the PUBCOL indicator for the whole Duero basin (€/ha·year)**

PUBCOL (€/ha)	Water price		
	'Subsidized' price 0.02 €/m^3	'Medium' price 0.04 €/m^3	'FCR' price 0.06 €/m^3
Agenda 2000 (Current PUBCOL =0)	122	197	193
World Markets (Current PUBCOL =0)	130	210	179
Global Sustainability (Current PUBCOL =0)	121	201	260
Provincial Enterprise (Current PUBCOL =0)	132	236	302
Local Stewardship (Current PUBCOL =0)	102	170	191

Source: Authors' own analysis

As can be seen, the highest collection is obtained for the Provincial Enterprise scenario (132-302 €/ha·year), while the Local Stewardship scenario produces the least impact of pricing (102-191 €/ ha·year).

In any case, even more important than the scenario comparison, is identifying the water price that would maximise revenue to the public sector. For the "*status quo*" and World Markets scenarios this threshold limit is located at around 0.05 €/m^3. For the other scenarios, the maximum collection could be obtained at a price above 'FCR' (around 0.08 €/m^3). However, regardless of the scenario considered, only if users are willing to pay for irrigation water savings will water pricing be efficient. Otherwise, as a last resort society as a whole should assume an economic inefficiency.

4.3. Social impact

4.3.1.- *Agricultural labour (EMPLOY)*

Table 7.16 shows the changes estimated for the social indicator related to labour generated by the agricultural sector if the various water prices were implemented.

As shown in the following table, the employment generated by the irrigated agriculture would suffer the greatest drops under Local Stewardship, while the lowest drops would result from Provincial Enterprise. In any case, considering that farmers and their relatives supply most labour in family farms, this decrease in the EMPLOY indicator would primarily translate into an increase in the leisure time available to these producers.

Table 7.16. Changes in the EMPLOY indicator for the whole Duero basin (person·day/ha)*

EMPLOY (person-day/ha)	Water price		
	'Subsidized' price 0.02 €/m^3	**'Medium' price 0.04 €/m^3**	**'FCR' price 0.06 €/m^3**
Agenda 2000 (Current EMPLOY =1.53)	-0.12 (-7.68%)	-0.34 (-22.50%)	-0.63 (-40.96%)
World Markets (Current EMPLOY =1.79)	-0.13 (-7.51%)	-0.36 (-20.34%)	-0.78 (-43.65%)
Global Sustainability (Current EMPLOY =1.73)	-0.16 (-9.15%)	-0.35 (-20.11%)	-0.48 (-27.56%)
Provincial Enterprise (Current EMPLOY =1.61)	-0.05 (-3.31%)	-0.16 (-9.76%)	-0.28 (-17.30%)
Local Stewardship (Current EMPLOY =1.55)	-0.25 (-15.89%)	-0.41 (-26.41%)	-0.60 (-38.98%)

* The percentages resulting in the decrease of the indicators vis-à-vis the current situation are shown in parentheses.
Source: Authors' own analysis

4.3.2.- *Seasonality (SEASONA)*

Table 7.17 collects the seasonality estimates made for each scenario and water price:

Table 7.17. Changes in the SEASONA indicator for the whole Duero basin (%)

SEASONA (%)	Water price		
	'Subsidized' price 0.02 €/m^3	**'Medium' price 0.04 €/m^3**	**'FCR' price 0.06 €/m^3**
Agenda 2000 (Current SEASONA =71%)	-0.43%	0.58%	-3.91%
World Markets (Current SEASONA =56%)	-0.78%	-2.47%	0.77%
Global Sustainability (Current SEASONA =59%)	-0.60%	1.63%	2.08%
Provincial Enterprise (Current SEASONA =56%)	-0.39%	-0.58%	-0.48%
Local Stewardship (Current SEASONA =65%)	1.37%	-0.86%	-3.13%

Source: Authors' own analyses

Table 7.17 shows that labour seasonality is more dependent on the policy scenario than on the water prices implemented. In fact, the "*status quo*" scenario is that in which the SEASONA indicator is the highest, in spite of the water price considered, while seasonal effects are lowest in World Markets, Provincial Enterprise and Global Sustainability.

Thus, stabilisation of the rural population is achieved more efficiently by means of agricultural policy than via water pricing.

4.4. Landscape and biodiversity

4.4.1.- *Biodiversity (DIVERS)*

The following table shows the estimated changes in the number of crops that would be abandoned within the Duero Valley in the different policy scenarios proposed if water tariffs were implemented.

Table 7.18. Changes in the DIVERS indicator for the whole Duero basin (€/ha·year)*

DIVERS (no. crops)	Water price		
	'Subsidized' price 0.02 €/m^3	**'Medium' price 0.04 €/m^3**	**'FCR' price 0.06 €/m^3**
Agenda 2000 (Current DIVERS =7)	0 (0.00%)	0 (0.00%)	0 (0.00%)
World Markets (Current DIVERS =7)	1 (14.29%)	0 (0.00%)	-1 (-14.29%)
Global Sustainability (Current DIVERS =8)	0 (0.00%)	0 (0.00%)	0 (0.00%)
Provincial Enterprise (Current DIVERS =9)	0 (0.00%)	0 (0.00%)	0 (0.00 %)
Local Stewardship (Current DIVERS =9)	0 (0.00%)	-1 (-11.11%)	-1 (-11.11%)

* The percentages resulting in the decrease of the indicators vis-à-vis the current situation are shown in parentheses.
Source: Authors' own analysis

As can be seen, the number of crops cultivated in the analysed irrigated area is more dependent on policy scenario than on the water price. In fact, the Provincial Enterprise and Local Stewardship scenarios would result in a higher number of crops (9) than the other ones. Once the policy scenario has been fixed, the DIVERS indicator remains the same for the different tariffs, or only shows slight changes.

4.4.2.- *Soil cover (SOILCOV)*

Table 7.19 shows the evolution of the soil cover in each case:

Table 7.19. Changes in the SOILCOV indicator for the whole Duero basin (%)

SOILCOV (%)	Water price		
	'Subsidized' price 0.02 €/m^3	**'Medium' price 0.04 €/m^3**	**'FCR' price 0.06 €/m^3**
Agenda 2000 (Current SOILCOV =66%)	-0.95%	-4.44%	-7.68%
World Markets (Current SOILCOV =74%)	-1.63%	-6.97%	-11.10%
Global Sustainability (Current SOILCOV =64%)	-1.65%	-3.95%	-6.57%
Provincial Enterprise (Current SOILCOV =64%)	-1.13%	-2.59%	-4.69%
Local Stewardship (Current SOILCOV =57%)	-2.70%	-5.20%	-8.36%

Source: Authors' own analysis

As can be seen, the changes experiences by the SOILCOV indicator are due to policy scenarios and water tariffs. In this case both policies are equally important. In sum, the policy scenario where the maximum soil cover is found under a zero-rate water tariff is World Markets (74%), although this scenario also produces the highest reductions in SOILCOV (from -2% to -11%). On the other hand, the lowest soil cover with current water pricing (0.00 €/m^3) is located paradoxically in the Local Stewardship scenario. Finally, it is worth noting that the smallest decreases in this indicator are located in the Provincial Enterprise scenario (from -1% to -5%).

Thus, if avoiding soil erosion is a political objective, both policies should be managed properly in order to obtain efficient results. Only the establishment of policy frameworks that promote the cultivation of crops that remain for long periods in the soil, such as maize, sugar-beet or alfalfa (those with higher water requirements), would achieve such an objective.

4.5. Environmental impact

4.5.1.- *Nitrogen balance (BALNIT)*

Table 7.20 illustrates the variations experienced in this indicator for each policy scenario and water price:

Table 7.20. Changes in the BALNIT indicator for the whole Duero basin (kg of N/ha)*

BALNIT (kg N/ha)	Water price		
	'Subsidized' price 0.02 €/m^3	**'Medium' price 0.04 €/m^3**	**'FCR' price 0.06 €/m^3**
Agenda 2000 (Current BALNIT =138)	-19 (-13.41%)	-55 (-39.55%)	-81 (-58.75%)
World Markets (Current BALNIT =101)	-9 (8.63%)	-24 (23.57%)	-50 (49.79%)
Global Sustainability (Current BALNIT =50)	-3.28 (-6.55%)	-10 (-20.15%)	-15 (-30.89%)
Provincial Enterprise (Current BALNIT =36)	-1 (-3.48%)	-3 (-8.97%)	-7 (-20.20%)
Local Stewardship (Current BALNIT =38)	-7 (-18.24%)	-12 (-32.87%)	-20 (-51.98%)

* The percentages resulting in the decrease of the indicators vis-à-vis the current situation are shown in parentheses.
Source: Authors' own analysis

For this indicator we can point out that policy scenario is more relevant than the range of water prices as a means of modifying nitrogen balance. It is worth noting that Provincial Enterprise and Local Stewardship scenarios offer the lowest risk of producing non-point source pollution for nitrogen. In both cases, the consumption of this kind of fertilizer is so low for the current prices of water (0.00 €/m^3) that water pricing would produce only minor reductions. On the other hand, scenarios that present the highest values of BALNIT indicator in the current situation ("*status quo*" and World Markets) are those under which the implementation of water tariffs would have the greatest impact on reducing nitrogen discharges to the environment. These results thus demonstrate that agricultural policy is the most effective way of dealing with the chemical pollution produced by agriculture. In fact, using a water pricing mechanism in order to achieve this kind of environmental objective is the wrong way to do it.

4.5.2.- *Energy balance (BALENE)*

For all policy scenarios and water prices considered, the results obtained by the long-term energy balance indicator simulations are shown in table 7.21:

For this indicator, the results suggest that water pricing is the most effective way of promoting energy savings (lower greenhouse gas generation). In fact, it can be observed that Local Stewardship (for 'subsidized' and 'medium' prices) and World Markets scenarios (up to 43% for a 'FCR' price) are those that would result in the greatest reductions. On the other hand, Provincial Enterprise would produce the lowest reductions in BALENE. These results imply that environmental issues dealing with energy are better dealt with by means of water pricing than agricultural policy.

Table 7.21. Changes in the BALENE indicator for the whole Duero basin (10^6 kcal/ha)*

BALENE (10^6 kcal/ha)	**Water price**		
	'Subsidized' price 0.02 €/m^3	**'Medium' price 0.04 €/m^3**	**'FCR' price 0.06 €/m^3**
Agenda 2000 (Current BALENE =15)	-1 (-5.87%)	-3 (-18.60%)	-5 (-34.43%)
World Markets (Current BALENE =15)	-1 (-7.70%)	-3 (-22.04%)	-6 (41.29%)
Global Sustainability (Current BALENE =15)	-1 (-9.30%)	-3 (-22.03%)	-4 (-29.19%)
Provincial Enterprise (Current BALENE =15)	-1 (-2.91 %)	-1 (-9.69%)	-3 (-17.62%)
Local Stewardship (Current BALENE =13)	-3 (-15.58%)	-3 (-24.84%)	-5 (-36.65%)

* The percentages resulting in the decrease of the indicators vis-à-vis the current situation are shown in parentheses.
Source: Authors' own analysis

4.5.3.- *Pesticide risk (PESTRISK)*

The following table analyses the impact of agricultural policy and water tariffs on the indicator related to pesticide use (PESTRISK):

Table 7.22. Changes in the PESTRISK indicator for the whole Duero basin (10^3 PR/ha)*

PESTRISK (10^3 PR/ha)	**Water price**		
	'Subsidized' price 0.02 €/m^3	**'Medium' price 0.04 €/m^3**	**'FCR' price 0.06 €/m^3**
Agenda 2000 (Current PESTRISK =21)	-1 (-6.83%)	-5 (-22.40%)	-10 (-50.71%)
World Markets (Current PESTRISK =15)	-3 (-16.37%)	-6 (-38.94%)	-10 (-61.94%)
Global Sustainability (Current PESTRISK =10)	-1 (-8.45%)	-4 (-33.82%)	-4 (-42.86%)
Provincial Enterprise (Current PESTRISK =12)	0 (-2.07%)	-1 (-6.21%)	-2 (-14.79%)
Local Stewardship (Current PESTRISK =9)	-3 (-30.57%)	-4 (-42.50%)	-5 (-55.54%)

* The percentages resulting in the decrease of the indicators vis-à-vis the current situation are shown in parentheses.
Source: Authors' own analysis

In this case, as with the BALNIT indicator, agricultural policy is more effective in reducing the use of these kinds of agrochemicals. In fact, all the policy scenarios considered indicate a lower use of pesticides under the current water tariff (0.00 €/m^3), reducing the current amount of 21·103 PR/ha to a range between 15·103 PR/ha (World Markets) and 9·103 PR/ha (Local Stewardship).

In any case, water pricing is also effective in this matter, in that it would bring about important decreases in the BALENE indicator. In thisrespect, it should be noted that the highest relative drops in this indicator can be found under the Local Stewardship and World Markets scenarios, while Global Enterprise displays the least decreases in relative terms.

4.6. Summary

Table 7.23 summarizes all the information collected in this section, and attempts to present a general overview of the usefulness of using water pricing and agricultural policy as policy markers in order to influence the value achieved by the indicators proposed.

Table 7.23. Impact of water pricing and agricultural policy on the different indicators for the whole Duero basin

INDICATOR	Water pricing	Agricultural policy	Coordination required
Consumption (m^3/ha)	Very important	Very important	Yes
	Economic indicators		
TGM (€/m^3)	Important	Very important	Yes
GDPCON (€/m^3)	Important	Very important	Yes
SUBSID (€/m^3)	Neutral	Very important	
PUBCOL (€/m^3)	Very important	Neutral	
	Social indicators		
EMPLOY (man-day/ha)	Important	Very important	Yes
SEASONA (%)	Neutral	Very important	
	Environmental indicators		
DIVERS (no. of crops)	Neutral	Important	
SOILCOV (%)	Very important	Very important	Yes
BALNIT (kg N/ha)	Important	Very important	Yes
BALENE (10^6 kcal/ha)	Important	Important	Yes
PESTRISK (10^3 PR/ha)	Very important	Very important	Yes

Generally speaking we can affirm that agricultural policy appears to be a more powerful set of policy instruments than water pricing. In any case, if the implementation of tariffs is being considered, coordination of both policies is essential.

5. CONCLUSIONS AND RECOMMENDATIONS

We believe that this case study has illustrated, first, the impact of the implementation of water pricing in such an extensive agricultural systems, and second, the links between environmental policy and agricultural policy, focusing on the possible evolution of CAP policy and WFD instruments.

Our results confirm that ***water pricing*** for this case study is a rather useful economic instrument to reduce agricultural consumption of water (high elasticity of demand), increase cost recovery and decrease non-point source pollution generated by fertilizers and pesticides.

Nevertheless, the implementation of higher tariffs would have highly negative impacts on farmers' incomes and on the employment generated by this sector, endangering the future of rural development in these areas. Even more, water pricing would have a negative environmental influence on soil erosion (soil cover indicator) and greenhouse gas emissions (energy balance indicator).

In this respect, it is worth noting that the objective of full-cost recovery included in the WFD would simply be impossible to achieve in the basin we have analysed, at least within the current CAP framework. The low value-added and heavily subsidised crops cultivated in these agricultural systems make the payment of water tariffs that cover all related costs unaffordable. In fact, the present irrigation infrastructure was developed during the 50s to 70s, not because of its economic profitability but because of its social value. This region in inner Spain had been suffering a serious depopulation problem that needed to be partially solved by intensifying farming practices (irrigation).The benefits obtained by this type of irrigated areas should therefore be considered as social rather than economic.

We have also realized that ***CAP*** is a more relevant policy than water pricing in order to achieve all the policy-makers' objectives (economic, social and environmental) in this kind of irrigated area. In fact, by appropriately implementing such instruments (commodities and input prices), most of the above-mentioned positive impacts dealing with water pricing (water consumption, pollution generated by fertilizers and pesticides, and reduced subsidies) could be obtained in a more efficient way, precisely because agricultural policy could minimize the negative impacts also mentioned (farmers' income and agricultural labour demand) at the same time. Thus, in general, it can be affirmed that agricultural policy can be regarded as a better means of attaining any policy objective that concerns extensive and marginally profitable irrigated areas.

In sum, as a policy recommendation, we suggest that the first issue that needs to be clarified is the ***policy objectives to be achieved in irrigated areas***. Thus, it is necessary to integrate the environmental objectives (clean water and the improvement of water ecosystems) of the WFD with those that guide the CAP (rural development with multifunctional agricultural systems). Only understanding the existing conflicts between both points of view and properly weighting their relative important for the society will a successful integration of these two sets of objectives be possible. Once the unique set of objectives has been defined, there is a wide range of policy instruments that can be implemented in order to achieve them. It is likely that the appropriate set of instruments will include water pricing and other classical instrument within agricultural policy.

In any case, a ***low volumetric water pricing*** would be necessary in these irrigated districts, precisely in order to make farmers conscious of the value of water to society as a whole and the importance of using it properly (efficient water distribution, modernization of infrastructure and cultivation of–higher value-added or labour -employment crops).

Simultaneous CAP reforms and (low) water pricing implementation are an important source of potential conflicts in such marginally profitable irrigated areas. It is likely that while any feasible future CAP will favour free trade and encourage the competitiveness of EU agriculture, implementation of the WFD (i.e. the full-cost recovery principle) would impose additional costs on irrigated farming, negatively affecting its competitiveness. This is why we suggest that the two policies should be closely co-ordinated in order to avoid major damage to irrigated areas (farms withdrawals). We believe that our research demonstrates that environmental goals (e.g. efficiency of water use) targeted via economic instruments (water price) can achieve the desired results without excessive negative impacts on farm income by combining the implementation of both policies in specific ways.

8

The case of Greece

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1. Background

Greece is a Mediterranean country with extensive irrigated agriculture. Geomorphology, geological structures, uneven distribution of rainfall in space and time and diminishing precipitation have all resulted in a scarcity of water during the peak period for irrigation. Since Greece has an arid climate, irrigated agriculture is more productive than dry-land agriculture, making irrigation one of the principal uses of water.

Irrigation was initially limited to horticulture and tree crops, but has now been extended to include arable crops such as cotton, maize and sugar beets. Agricultural irrigation uses 83% of water supplies in Greece. Surface water accounts for around 85% of the total quantity of water used, of which one-third has its origin outside the country.

The main characteristics of Greece and some statistics of Greek agriculture are briefly given below (see "Survey of Current Institutional Framework for Water Management in Greek Irrigated Agriculture" realized in the context of WADI project).

- Total Population: 10,498,836
- Employment in agriculture as % of active population: 18.7%

- Employment in agriculture as % of total civilian employment: 17.0%
- Total area: 13,196,000 ha
- Total utilized area: 29.3% of the total area
- Irrigated area: 37.2% of total utilized area
- Irrigated area from public networks 32.1%, private 67.9%
- Irrigated area per technology applied: gravity 36.9%, pressure 63.1%
- Irrigated area per method applied: Surface irrigation 37.5%, Sprinkler irrigation 52.2%, Drips irrigation 10.3%
- Irrigated area by type of water resources: Rivers 43.3%, Lakes 5.9%, Artificial Lakes 24.5%, Drills 23.0%, Drainage 3.2%
- Agricultural irrigation use: 83% - 89% of total water supplies
- There are 814 thousand agricultural holdings in Greece.
- The average area per agricultural holding is 4.4 hectares.

Law 1739/89 on the "Management of Water Resources" constitutes the current legislative framework for the management of water resources at both the national and regional levels. Under this law, Greece is divided into 14 water districts. Any legal entity or person must obtain, free of charge, a license for the use of water.

Sprinklers remain the dominant irrigation technology in Greek agriculture, while considerably slower adoption rates have been observed in drips irrigation. Traditional irrigation systems are more important in areas where irrigated land forms a small proportion of cultivated land *(Irrigated area per method applied: Surface irrigation 37.5%, Sprinkler irrigation 52.2%, Drips irrigation 10.3%)*. For all crop types and regions, the dominant system is support irrigation, lasting from late spring to early autumn. However, rice production in saturated systems is also a feature of some areas.

Generally, there is no specific connection between geographical region, irrigation technology and kind of crop. In fact, in most regions of Greece, for most crops, all types of irrigation systems can be found. Both groundwater and surface water sources are used and, in some cases, a small proportion of water is drawn from springs.

Nevertheless, we can distinguish several irrigated agricultural systems in Greece. Among the most important ones are the system consisting of fruit tree cultivation (apples, peaches, pears etc.) and other crops; the system consisting of arable crops with cotton as a basic crop; and the system consisting of arable crops with tobacco as a basic crop. These systems are found in the irrigated regions of Central and Northern Greece. Other irrigated agricultural systems are those which cultivate orange trees or vineyards etc as the basic crops.

In our case study we selected three specific irrigated areas of Greece with different irrigation characteristics which are representative of the country's three most common agricultural systems. These areas are part of the country's three main water districts. The first is the Prefecture of Pella in the region of Central Macedonia, in Northern Greece, which is representative of a fruit tree cultivation system. Most irrigation in this area is done by furrows and sprinklers and 48.5% is based on gravity and 51.5% on pressure. Main crops apart from fruit trees (peaches, apples and pears) are cotton and sugar beets. The second is the Prefecture of Larissa in the region of Thessalia, in Central Greece, which is representative of an agricultural system with high productivity. In this area, farmers use modern irrigation systems such as sprinklers and drips irrigation under pressurized pumped water from the Pinios River. Main crops are cotton and hard wheat. The third is the Prefecture of Xanthi in the region of East Macedonia and Thrace, in North-eastern Greece, which is representative of a common agricultural system. Here, most irrigation is done by sprinklers based on pressure. Main crops are corn, hard wheat and tobacco.

The technical and socio-economic characteristics of the three selected areas are presented in appendices 1, 2, 3 and 4.

In all three areas the climate is Mediterranean with the particular characteristic of dryness during the summer period. The land used for agriculture is a combination of both fertile and poor soils.

2. CASE STUDY DESCRIPTION, CLUSTERS DEFINITION

The selected irrigated areas described above all have different production plans: each region has one-two crops that the other regions do not have; the percentage distribution of crops in each region varies widely; and the most important crops of each region differ.

The production plans of each region are presented below. a) Pella: cereals, corn, alfalfa, cotton, sugar beats, tomatoes, fruit trees (no tobacco), b) Larissa: cereals, corn, alfalfa, cotton, sugar beets, (no tobacco or fruit trees), c) Xanthi: cereals, corn, alfalfa, tobacco, cotton, sugar beats, tomatoes (no fruit trees).

Concerning the main irrigation technology that exists in each of the three regions which can be used by farmers to irrigate their fields there are: Gravity (public networks) in the case of Pella; and pressure (public or private pumps) in the cases of Larissa and Xanthi. Irrigation methods include a) Surface irrigation b) Sprinkler irrigation c) Reel/Gun d) Drips irrigation. From the relevant survey the results show that farmers apply a variety of irrigation methods and technology depending on the specific crops of each region. However, there does not appear to be any connection between irrigation technology or method and the selected area.

A questionnaire was used to collect micro technical and economic data from seventy-three (73) farms of the regions under study, which were divided into three farm samples: twenty-five (25) farms are from Pella, twenty-five (25) from Larissa and twenty-three (23) from Xanthi.

With the application of Cluster analysis the farms of each region were separated into homogeneous groups in order to obtain the most representative farms. This categorization took into account objective parameters concerning a series of inputs and outputs so that the farms with similar characteristics were grouped together.

The Hierarchical Model was applied in order to place the farms of each region into homogeneous groups, taking into account all the available data on social, economic and technical characteristics (see appendices 2, 3, 4). The variables used were inputs and outputs concerning family size, farm size, the age of the head of the farm, the acreage of different crops of the farm plan, machinery, irrigation technology (types and methods of irrigation), variable capital, fertilizers, labour, crop production, income and profits.

From the analysis, three clusters were formed in each region: small, medium and large farms. These clusters can give us a good mapping of the farms. These results are in accordance with the fact that farm typology in Greece depends highly on farm size. This is due to two reasons. First, farm size in Greece is closely related to the crop plan, crop yields, labour, profits, investments in machinery and new technology (e.g. drips irrigation) etc. Second, farm size is considered as the major criterion for farm typology because the majority of farms are small in size (77% of farms are less than 5 ha and only 23% of farms are over 5 ha).

From the results of the cluster analysis we can conclude that there was no connection between irrigation systems, methods or technology and clusters in all irrigated areas. The main characteristic of each cluster was the farm size. Therefore, from each of the three selected irrigated regions we have taken three types of farms with different plans. The first farm type is constituted mainly from small producers (less than 5 ha). The second farm type represents the medium farms, which are similar to the farm plans of the region as a whole. The third farm type is constituted mainly from large farms.

3. WATER DEMAND & WATER PRICING IMPACT BY AGRICULTURAL SYSTEM

We used the MCDA model of weighted goal programming and the surrogate utility function in order to simulate farmers' decision-making processes as well as to estimate the value for the demand of water in the chosen irrigated areas, using utility-derived demand functions (for details see WADI reports D9 and D10).

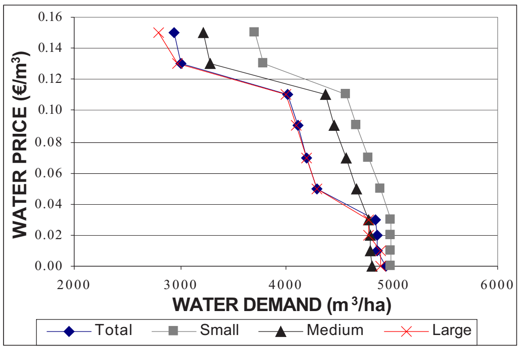
We applied this model to 5 cases for all clusters in the irrigated areas: Agenda 2000 (Status Quo) and the four Agricultural Policy Scenarios a) World Markets, b) Global Sustainability, c) Provincial Enterprise, d) Local Stewardship (for details see WADI deliverable D11).

3.1. Pella (Fruit tree cultivation)

3.1.1.- *Water use (demand m^3/ha) and crop plan decision*

As we can see from figure 8.1, the water demand in the region of Pella is highest for small farms followed by medium and large. Although the optimal farm plans for all the three types of farms are very similar, the number of cultivated hectares varies widely. When the water price is increased, all farm types decrease the demand for water. At three cents in the Euro, water consumption is reduced by 1.9%; when the price of water goes up to five cents there is a 13.1% reduction and at the end of the simulation (0.15 €/m^3) only 59.6% of the original consumption is used.

Figure 8.1. Water demand (m^3/ha) in relation to water price in Pella

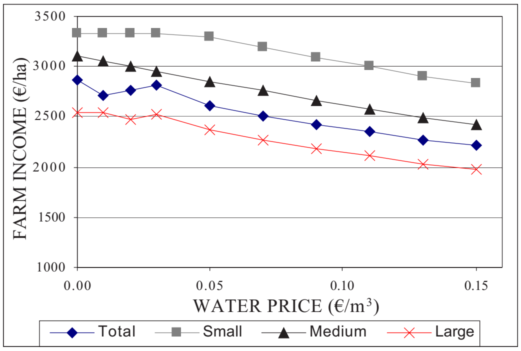


Price	Total	Small	Medium	Large
0.00	4945	4989	4805	4892
0.01	4865	4989	4799	4892
0.02	4858	4989	4793	4780
0.03	4851	4989	4788	4773
0.05	4299	4887	4672	4285
0.07	4201	4776	4565	4187
0.09	4107	4669	4463	4093
0.11	4017	4567	4366	4004
0.13	3009	3783	3291	2976
0.15	2946	3704	3222	2801

3.1.2.- *Economic balance*

In Pella, income is higher for small farms followed by medium and large farms. With an increase in the price of water, farm income declined. At the beginning of the simulation the farm income was 2,873 Euros per hectare but as water prices increase, it declines, in conjunction with the general trend of decreased water demand. When the price of water reaches fifteen cents in the Euro, farm income falls to 2,210 €/ha.

Figure 8.2. Farm income in relation to water price in the region of Pella

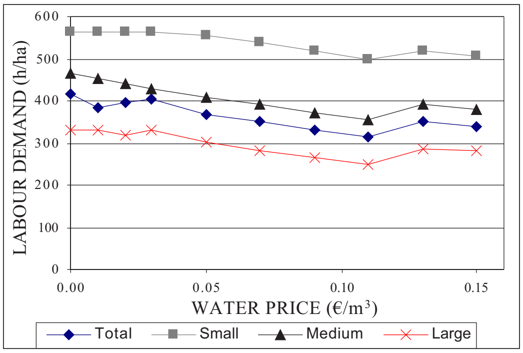


Price	Total	Small	Medium	Large
0.00	2873	3326	3101	2536
0.01	2708	3326	3054	2536
0.02	2762	3326	3006	2466
0.03	2815	3326	2958	2518
0.05	2604	3290	2856	2364
0.07	2514	3188	2758	2274
0.09	2428	3091	2665	2188
0.11	2346	2997	2576	2107
0.13	2267	2908	2490	2028
0.15	2210	2835	2427	1973

3.1.3.- *Social impact*

Agricultural employment is closely related to reduced water consumption. The amount of farm employment (man-days/ha) and seasonality is lower for all farm types. Farm employment is higher for small farms followed by medium and large farms. When the price of water increases, employment decreases, as does seasonal employment. The implications of this are that there is a negative social impact.

Figure 8.3. Labour demand in the region of Pella in relation to water price



Price	Total	Small	Medium	Large
0,00	415	563	466	329
0,01	384	563	454	329
0,02	395	563	442	319
0,03	406	563	430	330
0,05	367	557	410	301
0,07	349	537	390	283
0,09	332	518	372	266
0,11	315	499	354	250
0,13	351	519	391	287
0,15	339	505	379	282

3.1.4.- *Landscape and biodiversity*

In Pella, all categories of farms use their land for the cultivation of fruits (such as apples, pears, peaches) almost the whole year round. For this reason, landscape and biodiversity in all farm types did not appear to be affected by water prices.

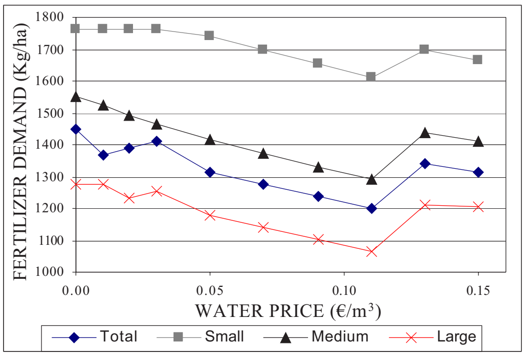
Table 8.1. Indicators-water price in the region of Pella – Total

Water price	Economic Balance		Social impact		Landscape and biodiversity		Water use	Environmental impact	
	Farm income (€/ha)	Public support (€/ha)	Farm employment (Man-days/ha)	Seasonality (Man-days /month)	Genetic diversity (No. of crops)	Soil cover	Water use (m^3/ha)	Nitrogen balance (kg/ha)	Energy balance (10^5 kcal/ha)
0.00	2872.8	1.9	414.5	34.5	6	App. whole year	4944.8	35.9	163.5
0.01	2708.4	1.9	384.4	32.0	6	App. whole year	4864.7	39.5	467.3
0.02	2761.7	1.9	395.4	33.0	6	App. whole year	4857.6	38.3	466.0
0.03	2814.5	1.9	406.3	33.9	6	App. whole year	4850.7	37.1	464.7
0.05	2604.2	15.3	366.6	30.5	6	App. whole year	4299.2	32.9	458.2
0.07	2514.3	17.9	348.7	29.1	6	App. whole year	4200.9	33.2	458.1
0.09	2428.4	20.3	331.6	27.6	6	App. whole year	4107.0	33.5	458.1
0.11	2346.3	22.6	315.3	26.3	6	App. whole year	4017.2	33.9	458.1
0.13	2267.5	52.0	350.7	29.2	5	App. whole year	3009.1	34.0	495.0
0.15	2209.8	53.6	339.2	28.3	5	App. whole year	2946.0	34.2	495.0

3.1.5.- *Environmental impact*

Concerning the environmental impact in relation to price change, it is possible to analyse the nitrogen inputs and the pesticide intensity indicators. When the water price is at one cent, there is a major shift downwards of these indicators. Afterwards, at the price range of 10 to 15 cents in the Euro, a minor increase of N inputs is detected, although the general trend is of a slight decrease.

Figure 8.4. Fertilizer demand in relation to water price in Pella



Price	Total	Small	Medium	Large
0.00	1449	1760	1554	1275
0.01	1365	1760	1524	1275
0.02	1389	1760	1494	1230
0.03	1412	1760	1464	1253
0.05	1315	1742	1418	1181
0.07	1274	1696	1374	1141
0.09	1236	1652	1332	1103
0.11	1199	1610	1292	1066
0.13	1338	1700	1439	1209
0.15	1312	1667	1411	1206

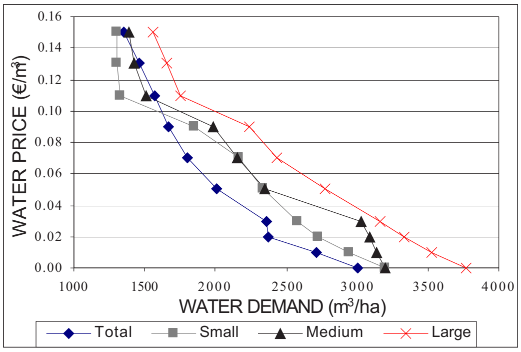
3.2. Larissa (High productivity cultivation, cotton, cereals)

3.2.1.- *Water use (demand m^3/ha) and crop plan decision*

The water consumption is lower for all farm types in this region. Large farms demand the most amount of water followed by medium and small. The crop plans include plants that require less water such as barley. In fact, the highest value for water demand at the zero pricing situation, rapidly diminishes above 0.02 €/m^3 to 2,369 m^3/ha, and even further at 7 cents to 1,798 m^3/ha. The lowest value for water demand at the end of the simulation was at 1,355 m^3/ha.

When water prices are low, the dominant crops in Agenda 2000 are: cotton, alfalfa, sugar beet and tomato, which are all irrigated. When the price is augmented there is a tendency to shift towards the rain fed equivalents, such as barley and hard wheat.

Figure 8.5. Water demand (m^3/ha) in relation to water price in Larissa

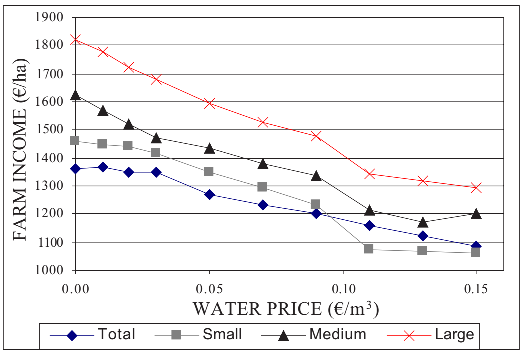


Price	Total	Small	Medium	Large
0.00	3009	3200	3203	3767
0.01	2710	2945	3143	3528
0.02	2368	2729	3085	3335
0,03	2364	2574	3030	3162
0.05	2005	2339	2351	2768
0.07	1798	2163	2149	2432
0.09	1671	1854	1980	2240
0.11	1570	1324	1514	1755
0.13	1459	1302	1429	1653
0.15	1355	1300	1387	1562

3.2.2.- *Economic balance*

In Larissa, farm income is lower for all farm types. It is higher for large farms followed by medium and small. The small farms were directly affected by water prices and farm income was very low. The economic balance although positive is low and decreases very rapidly for water prices between 0.05 €/m^3 and 0.15 €/m^3. Farm income begins at 1,361 €/ha, at nine cents it falls to 1,199 €/ha, which is a reduction of 12%. At fifteen cents in the Euro per cubic meter the income indicator has suffered a reduction of 20%.

Figure 8.6. Farm income in relation to water price in the region of Larissa



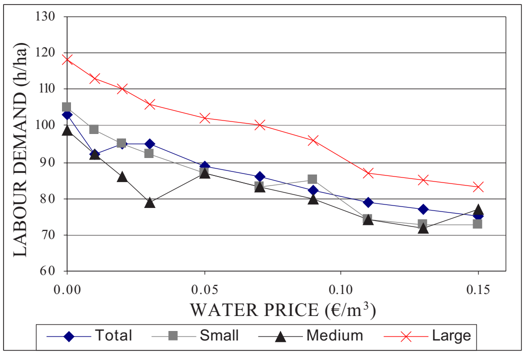
Price	Total	Small	Medium	Large
0.00	1361	1457	1625	1821
0.01	1368	1449	1571	1777
0.02	1352	1443	1519	1725
0.03	1348	1414	1469	1679
0.05	1267	1348	1434	1596
0.07	1231	1294	1380	1526
0.09	1199	1234	1335	1475
0.11	1161	1072	1216	1345
0.13	1122	1065	1171	1317
0.15	1085	1064	1200	1293

3.2.3.- *Social impact*

In this region, increased water prices had the effect of decreasing employment on all types of farms. Small farms had to reduce farm employment more than medium farms. The maximum amount of employment generated under the present Agenda 2000 policy is 103 h/ha at the zero water price.

The demand for labour progressively diminishes and at 0.11 €/m^3 22.8% of these labour units are no longer required. At the end of the simulation 27.5 % of labour needs have disappeared.

Figure 8.7. Labour demand in the region of Larissa in relation to water price



Price	Total	Small	Medium	Large
0.00	103	105	99	118
0.01	92	99	92	113
0.02	95	95	86	110
0.03	95	92	79	106
0.05	89	87	87	102
0.07	86	83	83	100
0.09	82	85	80	96
0.11	79	74	74	87
0.13	77	73	72	85
0.15	75	73	77	83

3.2.4.- *Landscape and biodiversity*

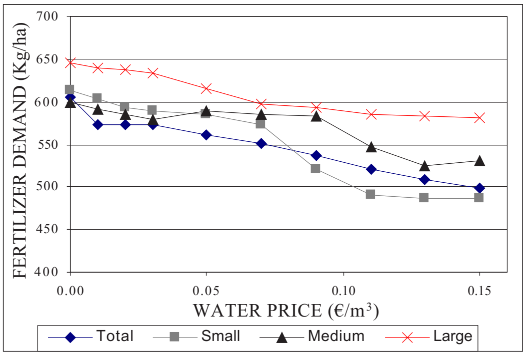
On small farms, the number of crops was reduced as water price increased. However, large and medium farms increased the number of crops in response to increased water prices.

Table 8.2. Indicators-water price in the region of Larissa – Total

Water price	Economic Balance		Social impact		Landscape and biodiversity		Water use	Environmental impact	
	Farm income (€/ha)	Public support (€/ha)	Farm employment (Man-days/ha)	Seasonality (Man-days /month)	Genetic diversity (No. of crops)	Soil cover	Water use (m^3/ha)	Nitrogen balance (kg/ha)	Energy balance (10^5 kcal/ha)
0.00	1360.7	139.05	102.7	12.8	7	App. 8 months	3.008.7	4.5	117.5
0.01	1368.3	147.61	92.4	11.5	7	App. 8 months	2.710.0	4.4	122.3
0.02	1352.3	166.15	94.9	13.6	7	App. 7 months	2.368.0	6.2	135.9
0.03	1347.9	182.76	94.8	13.5	6	App. 7 months	2.364.3	6.2	136.1
0.05	1267.5	211.04	88.7	12.7	6	App. 7 months	2.005.1	6.5	144.1
0.07	1231.4	233.72	85.9	14.3	6	App. 6 months	1.797.6	6.7	148.1
0.09	1199.2	252.20	82.4	13.7	5	App. 6 months	1.671.5	6.9	132.8
0.11	1160.9	298.89	79.3	15.9	6	App. 5 months	1.569.9	7.1	107.7
0.13	1121.9	308.73	76.7	15.3	5	App. 5 months	1.459.2	6.0	102.0
0.15	1084.7	317.49	74.5	14.9	5	App. 5 months	1.354.7	4.4	104.6

3.2.5.- *Environmental impact*

Figure 8.8. Fertilizer demand in relation to water price in Larissa



Price	Total	Small	Medium	Large
0.00	605	614	599	645
0.01	573	603	592	640
0.02	573	593	586	637
0.03	573	589	580	634
0.05	561	585	589	615
0.07	551	574	586	597
0.09	537	521	583	594
0.11	521	491	547	586
0.13	508	486	525	584
0.15	498	486	530	582

Rising water prices had a positive impact on the environment. Both N inputs and pesticide indicators show a tendency to decline as water prices increase (-18%).

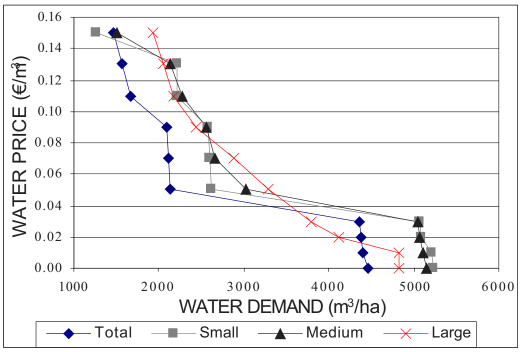
3.3. Xanthi (Common agricultural system, tobacco, corn)

3.3.1.- *Water use (demand m^3/ha) and crop plan decisions*

In the Xanthi region, there does not appear to be a response in the demand curve until the point of three cents to the Euro per cubic meter. The variation caused by this price increase is only 2.3% of the original consumption (4,462 m^3/ha). At the price of 0.05 €/m^3 the water saving at 52.3%, which makes this price the most promising for farmers to attain substantial reductions in water consumption.

The most important crops are irrigated tobacco, corn, cotton, alfalfa and rain fed durum wheat.

Figure 8.9. Water demand (m^3/ha) in relation to water price in Xanthi

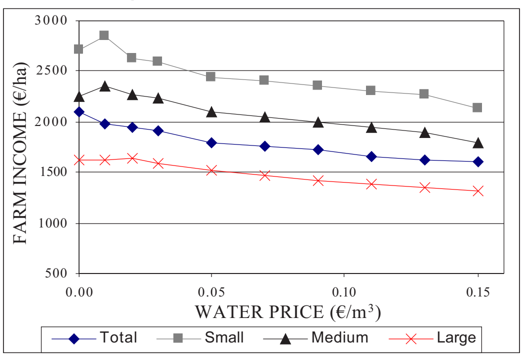


Price	Total	Small	Medium	Large
0.00	4462	5231	5158	4816
0.01	4398	5217	5113	4816
0.02	4379	5090	5069	4111
0.03	4360	5068	5047	3791
0.05	2129	2613	3024	3281
0.07	2111	2591	2665	2892
0.09	2093	2569	2565	2434
0.11	1662	2224	2284	2177
0.13	1559	2206	2141	2056
0.15	1468	1266	1496	1935

3.3.2.- *Economic balance*

An increase in the price of irrigation water had the effect of reducing the income on all farms. Despite this fact, public support to the agricultural sector remains unchanged for all farm types. A water price of 0.03 €/m^3 causes an income reduction of 9% (from 2,104 €/ha to 1,915 €/ha) and doubling that (0.06 €/$m^{3)}$ brings the income to 1,759 €/ha. At the end of the water price parameterisation, farm earnings are 1,603 €/ha. What tends to happen is that direct public subsidies are reduced as the water price increases.

Figure 8.10. Farm income in relation to water price in the region of Xanthi

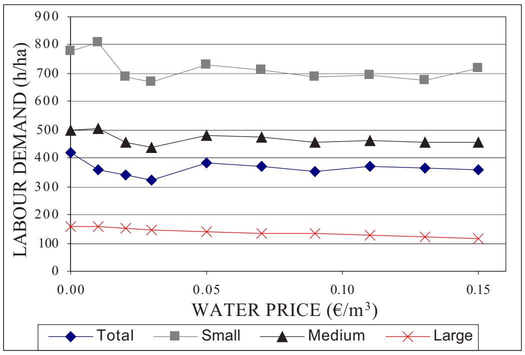


Price	Total	Small	Medium	Large
0.00	2104	2706	2252	1630
0.01	1985	2851	2349	1630
0.02	1950	2626	2268	1635
0.03	1915	2585	2227	1590
0.05	1789	2439	2093	1519
0.07	1756	2399	2043	1464
0.09	1723	2358	2002	1419
0.11	1661	2296	1944	1383
0.13	1630	2262	1902	1348
0.15	1603	2138	1787	1312

3.3.3.- *Social impact*

For water prices below 0.03 €/m³, the demand for agricultural labour is reduced. Above this price, although initially the agricultural employment increases, it then decreases again. At the zero water price, labour needs are 422 h/ha, which constantly decrease until the 0.03 €/m³ mark. When the price of water is set at 0.05 €/m³, labour reduction is 8.5, while at the end of the simulation the decrease is 14.4%.

Figure 8.11. Labour demand in the region of Xanthi in relation to water price



Price	Total	Small	Medium	Large
0.00	422	780	499	161
0.01	359	809	502	161
0.02	341	689	458	153
0.03	322	668	437	148
0.05	386	731	481	139
0.07	368	710	475	133
0.09	351	688	458	133
0.11	370	696	460	128
0.13	365	678	454	123
0.15	361	715	456	117

3.3.4.- *Landscape and biodiversity*

Rising water prices has the same results as in Larissa in terms of soil cover and genetic diversity in all farm types except for small farms in the genetic diversity, which means that the genetic diversity of small farms is lower than in Larissa.

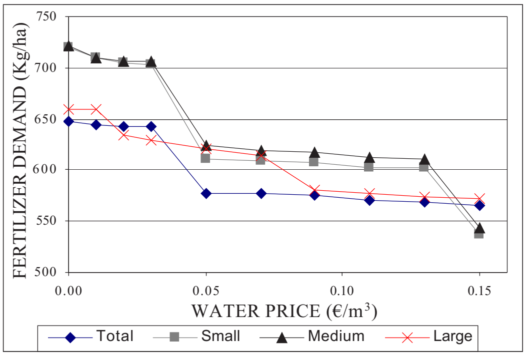
Table 8. 3. Indicators-water price in the region of Xanthi –Total

Water price	Economic Balance		Social impact		Landscape and biodiversity		Water use	Environmental impact	
	Farm income (€/ha)	Public support (€/ha)	Farm employment (Man-days/ha)	Seasonality (Man-days /month)	Genetic diversity (No. of crops)	Soil cover	Water use (m³/ha)	Nitrogen balance (kg/ha)	Energy balance (10⁵ kcal/ha)
0.00	2103,8	263,9	422	52,7	8	App. 8 months	4462,0	1324,6	200,7
0.01	1985.1	272.2	359	51.3	8	App. 7 months	4397.8	1332.9	205.4
0.02	1950.1	274.6	341	48.6	8	App. 7 months	4378.9	1335.4	205.8
0.03	1915.3	277.0	322	46.0	8	App. 7 months	4360.1	1337.8	206.3
0.05	1788.8	242.0	386	64.3	7	App. 6 months	2128.6	1136.2	128.2
0.07	1755.6	244.3	368	61.4	7	App. 6 months	2110.6	1138.5	128.6
0.09	1723.0	246.6	351	58.5	7	App. 6 months	2093.0	1140.8	129.1
0.11	1660.8	284.3	370	61.7	7	App. 6 months	1662.4	1175.1	136.6
0.13	1630.2	293.7	365	60.9	7	App. 6 months	1558.6	1183.8	138.5
0.15	1603.1	301.4	361	60.2	7	App. 6 months	1468.0	1191.4	140.1

3.3.5.- *Environmental impact*

Both nitrogen inputs and pesticide indicators register a significant reduction. Although, during most of the water price simulations the pesticide risk indicator remains unchanged, for prices above 0.05 €/m³, significant changes occur. The N inputs gradually diminish for water prices above 0.05 €/m³.

Figure 8.12. Fertilizer demand in relation to water price in Xanthi



Price	Total	Small	Medium	Large
0.00	647	720	721	659
0.01	644	710	709	659
0.02	643	704	707	635
0.03	643	703	706	629
0.05	578	610	625	620
0.07	577	609	619	614
0.09	576	608	617	581
0.11	570	603	612	577
0.13	568	602	610	574
0.15	566	537	544	572

4. RESULTS BY SCENARIO

4.1. Pella (Fruit trees)

4.1.1.- *Water demand and crop plan decisions (m^3/ha)*

The water demand at the initial zero price is highest (5,140.1m^3/ha) for the Global Sustainability scenario followed by the Provincial Enterprise (5,097.3m^3/ha), Local Stewardship (4,910.4m^3/ha) and the World Markets scenarios (4,569.9m^3/ha). The curves move in an almost parallel direction up to the point where the price of water is 0.03 €/m^3. The Global Sustainability and Provincial Enterprise scenarios seem to follow a similar pattern. The Agenda 2000 and Local Stewardship scenarios curves also move in parallel directions. The World Markets scenario presents lower water demand in comparison with all other scenarios for all water prices.

Table 4, shows that crop plans are stable in all except the World Markets scenarios. Barley, corn and pears are present only in this scenario. Cotton, sugar beets and peaches are dominant in all the other scenario crop plans apart from the World Markets scenario.

Table 8.4. Crop distributions in the region of Pella

Simulated crops areas (100 ha)	Agenda 2000	World Markets	Global Sustainability	Provincial Enterprise	Local Stewardship
TOTAL FARMS:					
1. Wheat	-	-	-	-	-
2. Barley	-	12.54	-	-	-
3 Corn	-	16.37	-	-	-
4. Alfalfa	5.05	10.00	4.91	10.00	3.70
5. Tobacco	-	-	-	-	-
6. Cotton	28.10	-	28.10	22.24	28.10
7. Sugar beets	26.80	2.80	26.80	26.80	26.80
8. Tomatoes	10.00	-	10.00	10.00	10.00
9. Peaches	25.05	26.40	25.19	25.96	26.40
10. Apples	5.00	-	5.00	5.00	5.00
11. Pears	-	5.00	-	-	-
12. Rice	-	-	-	-	-
13. Set Aside	-	2.89	-	-	-

Figure 8.13. Water demand (m^3/ha) among scenarios in relation to water price in Pella region

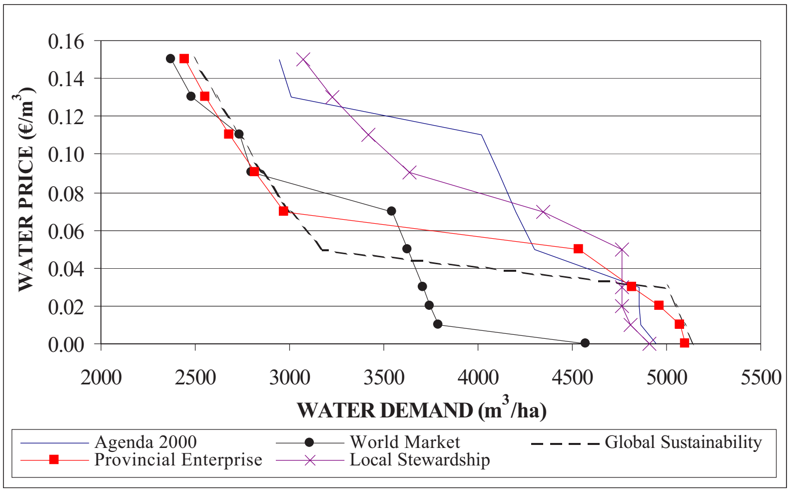
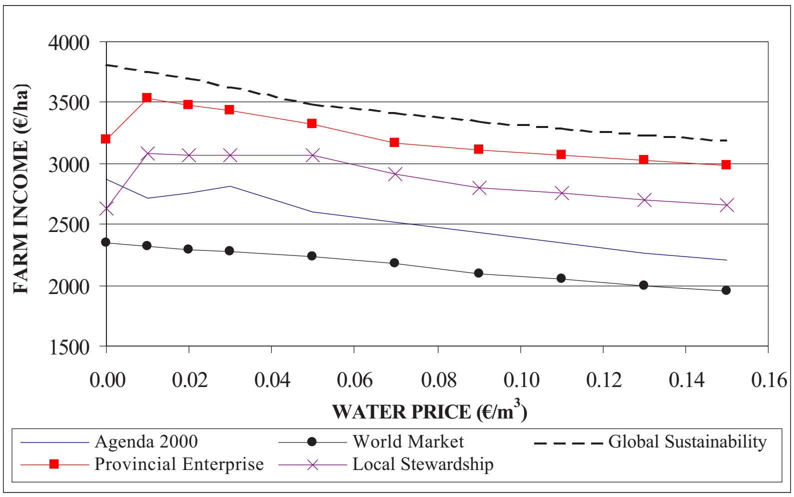


Table 8.5. Water demand (m^3/ha) among scenarios in relation to water price in Pella region

Price €/m^3	Agenda 2000	World Markets	Global Sustainability	Provincial Enterprise	Local Stewardship
0.00	4944.8	4569.9	5140.1	5097.3	4910.4
0.01	4864.7	3790.6	5092.1	5073.6	4810.7
0.02	4857.6	3748.4	5045.3	4965.2	4762.5
0.03	4850.7	3707.4	4998.4	4814.9	4763.9
0.05	4299.2	3627.1	3173.0	4540.5	4761.5
0.07	4200.9	3547.6	3001.8	2971.7	4347.4
0.09	4107.0	2796.5	2856.7	2819.7	3636.5
0.11	4017.2	2736.3	2725.0	2682.5	3419.6
0.13	3009.1	2482.2	2604.9	2558.0	3227.2
0.15	2946.0	2370.2	2494.9	2444.5	3073.9

4.1.2.- *Economic balance*

Figure 8.14. Farm income among scenarios in Pella region (total farms)

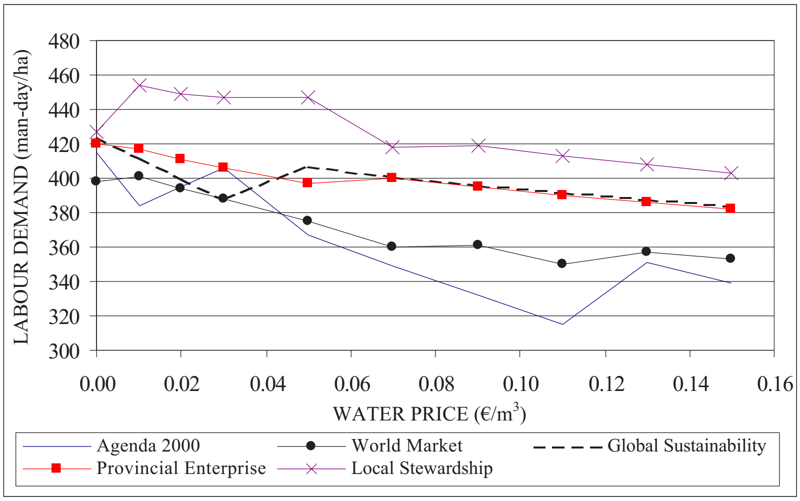


Farm income is the highest for the Global Sustainability scenario (3,816 €/ha) followed by Provincial Enterprise (3,196.24 €/ha), Local Stewardship (2,634.48 €/ha) and the World Markets scenarios (2,344.74 €/ha) for all water prices. However, at the zero price, farm income is higher in the Agenda 2000 scenario than the World Markets and Local Stewardship scenarios but is lower than the Global Sustainability and Provincial Enterprise scenarios. It is important to note that public support to the farmers in the study areas for the all scenarios is almost the same as Agenda 2000 except for the World Markets scenario.

4.1.3.- *Social impact*

The Local Stewardship scenario is the highest in comparison to the others for farm employment at 426.87 man-days/ha, which. In Agenda 2000, farm employment is lower than in the other scenarios except for that of the World Markets scenario but at the end of the simulation Agenda 2000 is the lowest for all scenarios. Seasonality, on the other hand, is the lowest for the World Markets (33.16 man-days/month) scenario, however, it is almost the same in all the scenarios except for the World Markets.

Figure 8.15. Farm employment among scenarios in Pella region (total farms)



4.1.4.- *Landscape and biodiversity*

The genetic diversity is the same as Agenda 2000 for all types of scenarios. In the region of Pella, the farmers produce fruits such as apples, pears, peaches and they use their land almost the whole year for this purpose. For this reason, the different scenarios had no effect on the landscape and biodiversity in this study area. Scenarios in this section were compared at 0€/m^3 of the water price.

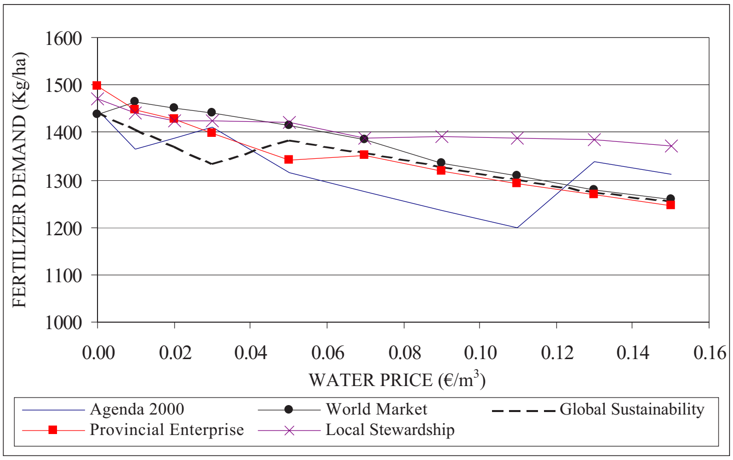
Table 8.4. Indicators-scenario for total farms in Pella region

Scenario	Economic Balance		Social impact		Landscape and biodiversity		Water use	Environmental impact	
	Farm income (€/ha)	Public support (€/ha)	Farm employment (Man-days/ha)	Seasonality (Man-days /month)	Genetic diversity (No. of crops)	Soil cover	Water use (m^3/ha)	Nitrogen balance (kg/ha)	Energy balance (10^5 kcal/ha)
Agenda 2000	2872.81	0.14	414.55	34.55	6	App. whole year	4944.81	1.43	433.47
World Markets	2344.74	117.84	397.87	33.16	6	App. whole year	4569.88	2.90	519.27
Global Sustainability	3816.0	0.14	423.9	34.65	6	App. whole year	5140.1	1.30	433.32
Provincial Enterprise	3196.24	0.11	419.93	34.99	6	App. whole year	5097.33	5.09	446.26
Local Stewardship	2634.48	0.14	426.87	35.57	6	App. whole year	4910.36	0.17	432.10

4.1.5.- *Environmental impact*

Energy balance was the highest for the World Markets scenario followed by the Provincial Enterprise, Global Sustainability, and Local Stewardship scenarios. However, energy balance in Agenda 2000 is similar to the Global Sustainability and Local Stewardship scenarios. The World Markets scenario had a strong effect on energy balance. On the other hand, nitrogen balance is the highest in the Provincial Enterprise scenario at the zero price but at the end of the simulation it is the lowest of all the scenarios.

Figure 8.16. Environmental impact among scenarios in Pella region (total farms)



4.2. Larissa (High productivity, cotton)

4.2.1.- *Water use demand (m^3/ha)*

The curves of all the scenarios move in an almost parallel direction except for the Agenda 2000 Scenario. In Larissa, the use of irrigation water was the highest for the Local Stewardship scenario followed by the Global Sustainability, Provincial Enterprise and World Markets scenarios. The results show that the water used in Agenda 2000 is lower than all the scenarios except for the World Markets. The results suggest that an increase in the price of water causes approximately a 50% reduction in water demand in all the scenarios.

From table 8.6 we can see that crop plans change in all the scenarios in relation to Agenda 2000. Sugar beets and alfalfa are the only crops that stay stable in all the crop plan scenarios. Cotton stays stable in all the scenarios except for the World Markets, while all the other crops change in percentages.

Figure 8.17. Water demand (m^3/ha) among scenarios in relation to water price in Larissa region

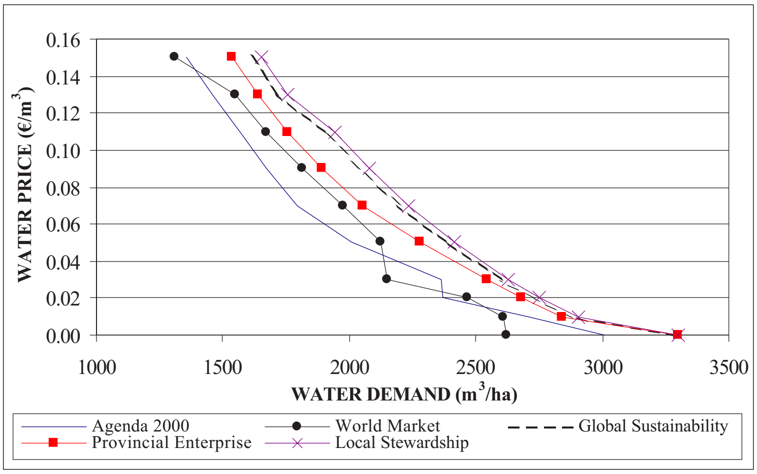


Table 8.5. Water demand (m^3/ha) among scenarios in relation to water price in Larissa region

Price €/m^3	Agenda 2000	World Markets	Global Sustainability	Provincial Enterprise	Local Stewardship
0.00	3008.7	2618.6	3296.6	3296.6	3296.6
0.01	2710.0	2610.1	2888.8	2840.3	2905.9
0.02	2368.0	2467.6	2731.3	2679.5	2753.8
0.03	2364.3	2151.6	2603.0	2545.2	2627.9
0.05	2005.1	2126.0	2379.9	2277.8	2412.1
0.07	1797.6	1974.7	2194.3	2051.8	2230.7
0.09	1671.5	1813.7	2037.6	1893.7	2076.2
0.11	1569.9	1672.2	1903.6	1758.2	1944.2
0.13	1459.2	1552.1	1714.7	1640.8	1756.5
0.15	1354.7	1309.6	1611.9	1538.1	1654.2

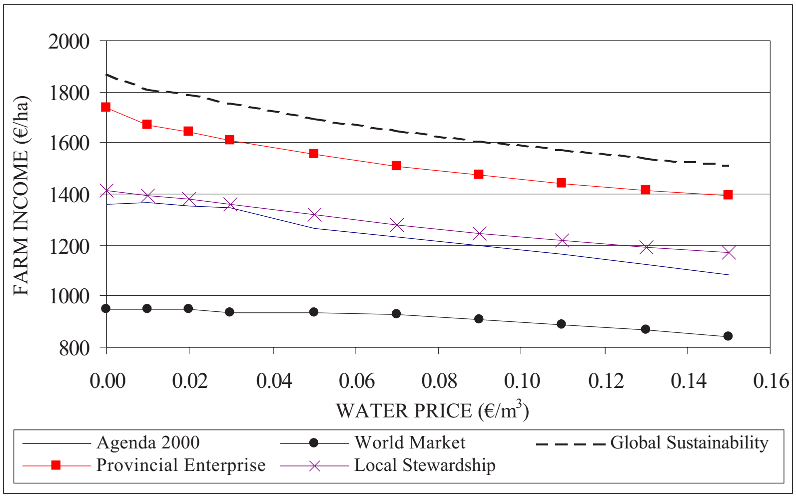
Table 8.6. Crop distributions in the regions of Larissa

Simulated crops areas (100 ha)	Agenda 2000	World Markets	Global Sustainability	Provincial Enterprise	Local Stewardship
TOTAL FARMS:					
1. Wheat	-	-	-	-	-
2. Barley	7.42	60.00	18.13	33.40	38.27
3 Corn	-	-	10.00	10.00	10.00
4. Alfalfa	3.60	3.60	3.60	3.60	3.60
5. Cotton	40.00	13.10	40.00	40.00	40.00
6. Sugar beets	3.30	3.30	3.30	3.30	3.30
7. Tomatoes	7.15	10.00	1.51	5.36	-
8. Wheat hard	34.35	-	18.76	-	-
9. Set Aside	4.18	10.00	4.69	4.34	4.83

4.2.2.- *Economic balance*

Farm income is highest in the Global Sustainability scenario followed by the Provincial Enterprise, Local Stewardship and World Markets scenarios at all water prices. In the Agenda 2000 scenario, the farm income curve is similar to the Local Stewardship scenario. However, public support to farmers is the highest for the Global Sustainability scenario than any other scenario. Public support (201.62 €/ha) to farmers in this area is higher in Agenda 2000 than all the other scenarios.

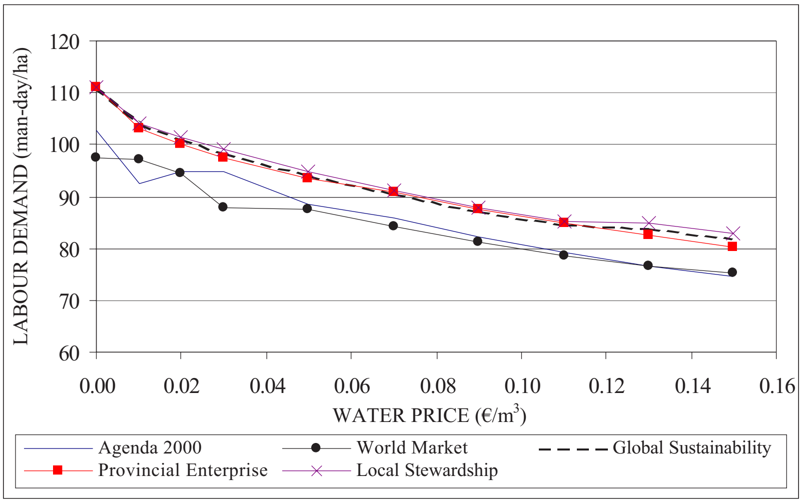
Figure 8.18. Farm income among scenarios in Larissa region (total farms)



4.2.3.- *Social impact*

Farm employment is highest for Local Stewardship followed by Global Sustainability, Provincial Enterprise and World Markets. The results show that water prices had the effect of decreasing both employment and seasonality for all types of scenarios in comparison to Agenda 2000.

Figure 8.19. Farm employment among scenarios in Larissa region (total farms)



4.2.4.- *Landscape and biodiversity*

The price of water in the various scenarios changes the landscape and biodiversity. Genetic diversity is the highest for the Global Sustainability followed by Provincial Enterprise, Local Stewardship, and World Markets scenarios. The soils were covered for 7 months both for Global Sustainability and Provincial Enterprise, which is longer than the World Markets and Local Stewardship scenarios, and much longer than Agenda 2000.

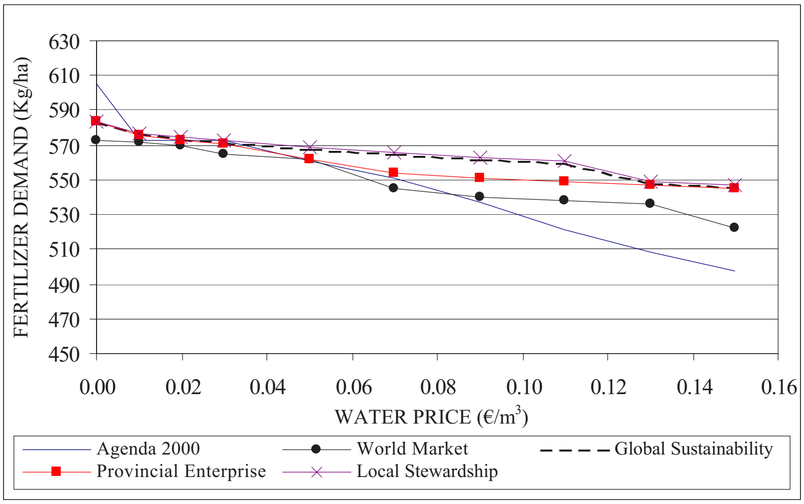
Table 8.7. Indicators-scenario for total farms in Larissa region

Scenario	Economic Balance		Social impact		Landscape and biodiversity		Water use	Environmental impact	
	Farm income (€/ha)	Public support (€/ha)	Farm employment (Man-days/ha)	Seasonality (Man-days /month)	Genetic diversity (No. of crops)	Soil cover	Water use (m^3/ha)	Nitrogen balance (kg/ha)	Energy balance (10^5 kcal/ha)
Agenda 2000	1360.71	201.62	102.74	17.12	7	App. 6 months	3008.74	21.02	413.19
World Markets	949.65	107.80	97.42	15.18	5	App. 5 months	2618.55	7.75	79.15
Global Sustainability	1874.9	188.11	111.1	13.03	8	App. 7 months	3296.6	11.46	266.71
Provincial Enterprise	1739.9	110.17	111.1	14.16	7	App. 7 months	3296.6	6.46	67.50
Local Stewardship	1414.0	118.23	111.1	13.95	6	App. 6 months	3296.6	4.61	68.39

4.2.5.- *Environmental impact*

The energy and nitrogen balance are the highest in the Global Sustainability scenario but lower than Agenda 2000. The environmental impact is the highest in Agenda 2000 compared to all other scenarios. Scenarios in this section were compared at the water price of 0 €/m^3.

Figure 8.20. Environmental impact among scenarios in Larissa region (total farms)

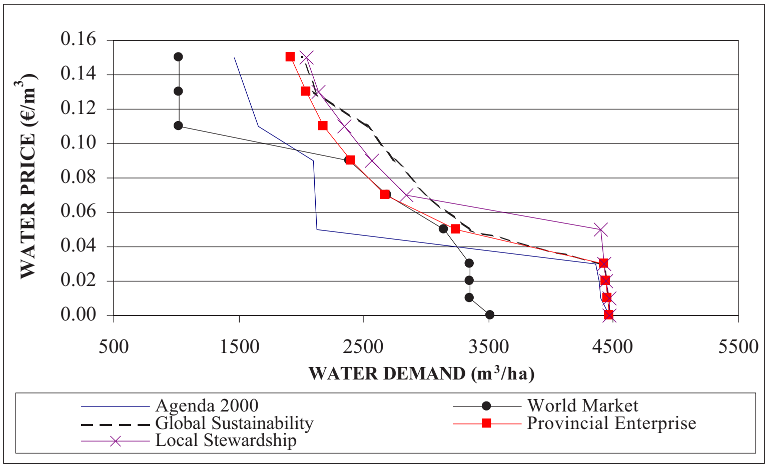


4.3. Xanthi (Common, tobacco)

4.3.1.- *Water demand (m^3/ha)*

The water demand curves of all the scenarios in this region are similar apart from the World Markets scenario. Water demand values close to 4,462 cubic meters per hectare are kept constant up to € 0.03/m^3. At this price, the water savings come to 20-35% of the initial value.

Figure 8.21. Water demand (m^3/ha) among scenarios in relation to water price in Xanthi region



The World Markets scenario has the lowest demand for water until being supplanted by the Agenda 2000 scenario where the price of water is 0.05 €/m^3. For prices above 0.11 €/m^3, the World Market scenario has lower water consumption than Agenda 2000.

Table 8.8. Water demand (m^3/ha) among scenarios in relation to water price in Xanthi region

Price €/m^3	Agenda 2000	World Markets	Global Sustainability	Provincial Enterprise	Local Stewardship
0.00	4462.0	3515.0	4462.0	4462.0	4462.0
0.01	4397.8	3353.0	4459.4	4455.4	4461.0
0.02	4378.9	3353.0	4443.5	4437.1	4446.0
0.03	4360.1	3353.0	4427.8	4418.9	4431.1
0.05	2128.6	3139.6	3348.3	3239.8	4401.6
0.07	2110.6	2689.2	3010.8	2672.4	2836.8
0.09	2093.0	2393.6	2742.0	2403.0	2568.9
0.11	1662.4	1025.4	2520.5	2182.9	2347.2
0.13	1558.6	1025.4	2113.2	2036.5	2134.4
0.15	1468.0	1025.4	1997.0	1919.3	2038.4

Table 8.9 shows that the crop plans are stable in all except the World Markets Scenario, where the choice of cotton is reduced and hard wheat is increased. All the other crops remain stable in farmers' crop plan decisions.

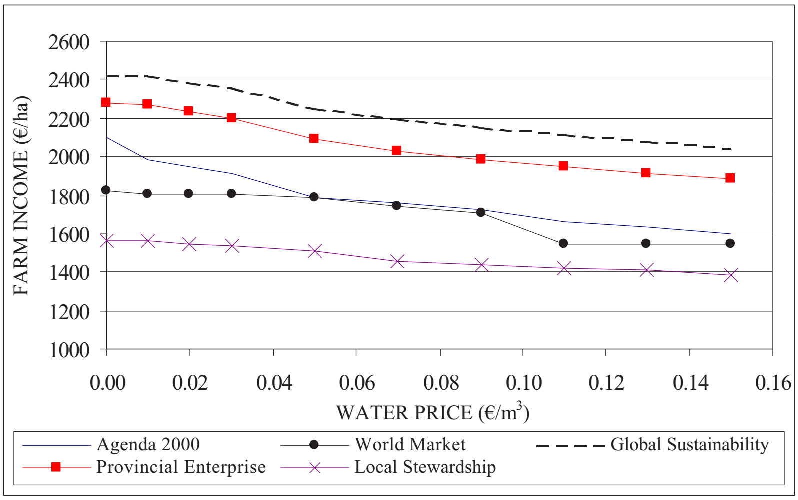
Table 8.9. Crop distributions in the region of Xanthi

Simulated crops areas (100 ha)		Agenda 2000	World Markets	Global Sustainability	Provincial Enterprise	Local Stewardship
TOTAL FARMS:						
1.	Wheat	-	-	-	-	-
2.	Barley	-	-	-	-	-
3	Corn	36.8	36.8	36.8	36.8	36.8
4.	Alfalfa	11.5	11.5	11.5	11.5	11.5
5.	Tobacco	8.2	8.2	8.2	8.2	8.2
6.	Cotton	15.3	2.10	15.3	15.3	15.3
7.	Sugar beets	2.2	2.2	2.2	2.2	2.2
8.	Tomatoes	10.00	10.00	10.00	10.00	10.00
9.	Wheat hard	11.2	23.2	11.2	11.2	11.2
10.	Set Aside	4.8	6	4.8	4.8	4.8

4.3.2.- *Economic balance*

Farm income is the lowest in the Local Stewardship scenario. It is the highest for Global Sustainability followed by the Provincial Enterprise, Agenda 2000 and World Markets scenarios for all water prices. On the other hand, the public support price had no remarkable effect on World Markets and Global Sustainability. The Provincial Enterprise and Local Stewardship scenarios, in comparison to the others, had little effect on the public sector.

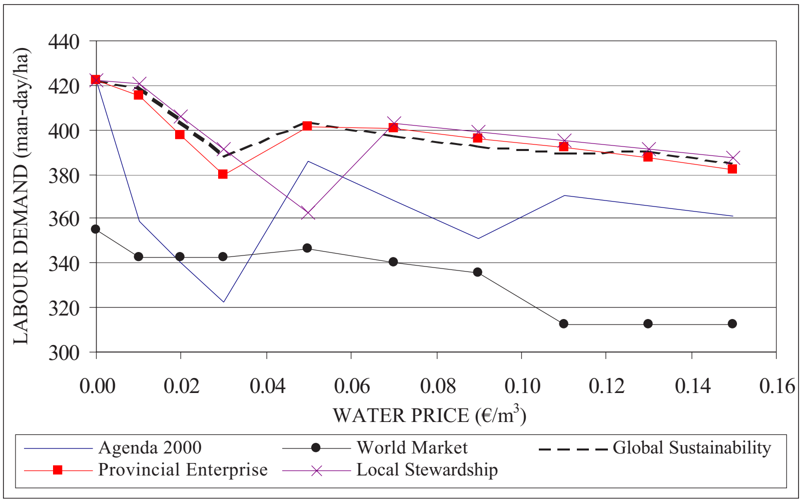
Figure 8.22. Farm income among scenarios in Xanthi region (total farms)



4.3.3.- *Social impact*

In the region of Xanthi, the results show that farm employment is lowest for the World Markets when compared to the other scenarios. Increasing the price of water had the effect of decreasing farm employment in all the scenarios, which are higher than Agenda 2000. In addition, compared to Agenda 2000, there was a reduction in seasonality.

Figure 8.23. Farm employment among scenarios in Xanthi region (total farms)



4.3.4.- *Landscape and biodiversity*

Genetic diversity is the highest in Global Sustainability than the other scenarios and it is the same in Agenda 2000. On the other hand, the farmers followed almost the same cropping mix as can be seen in the results of World Markets, Global Sustainability and Agenda 2000. Comparisons of the scenarios in this section were made at the water price of 0 €/m^3.

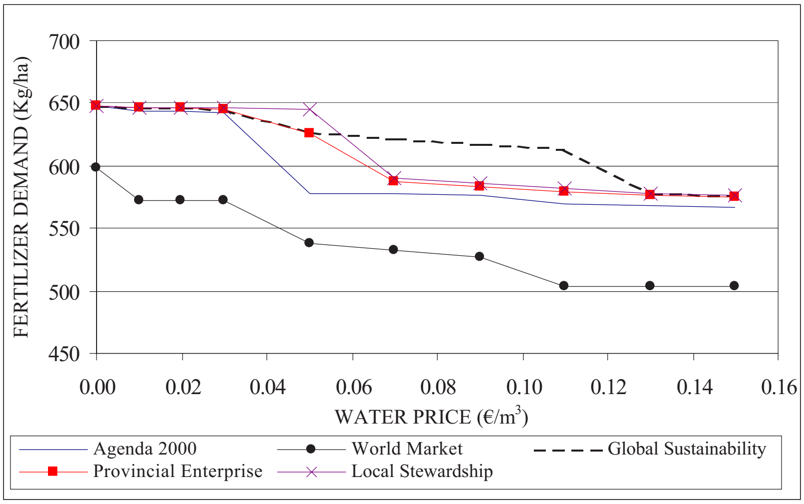
Table 8.10. Indicators-scenario for total farms in Xanthi region

Scenario	**Economic Balance**		**Social impact**		**Landscape and biodiversity**		**Water use**	**Environmental impact**	
	Farm income (€/ha)	Public support (€/ha)	Farm employment (Man-days/ha)	Seasonality (Man-days /month)	Genetic diversity (No. of crops)	Soil cover	Water use (m^3/ha)	Nitrogen balance (kg/ha)	Energy balance (10^5 kcal/ha)
Agenda 2000	2103.8	200.89	421.85	60.26	7	App. 7 months	4462	4.00	175.56
World Markets	1822.6	200.94	355.1	60.21	7	App. 7 months	3515.0	3.93	175.57
Global Sustainability	2424.4	200.89	421.85	60.26	8	App. 7 months	4462	3.93	175.56
Provincial Enterprise	2280.3	209.54	421.85	60.26	7	App. 6 months	4462	3.90	177.51
Local Stewardship	1561.34	209.54	421.85	60.26	7	App. 6 months	4462	3.90	177.51

4.3.5.- *Environmental impact*

It is very important to note that the energy balance was almost static for all types of scenarios and Agenda 2000. This result implies that the scenarios did not affect the energy balance in the region of Xanthi. The nitrogen balance is highest for Agenda 2000 when compared with the other scenarios, which are almost the same. Comparisons of the scenarios in this section were made at 0 €/m^3 of the water price.

Figure 8.24. Environmental impact among scenarios in Xanthi region (total farms)



5. CONCLUSIONS & RECOMMENDATIONS

Given that agricultural production in Greece is directly related to the availability of water, which is the most important limiting factor, the results obtained in this study of the three irrigated regions can make a significant contribution to the debate on the country's Agricultural policy.

As stated elsewhere in this study, the selected irrigated areas are representative of three of the most important irrigated agricultural systems in Greece. They were examined with the same assumptions in terms of both water pricing policy and agricultural policy scenarios. A Multicriteria Mathematical Programming model that simulates farmers' behaviour and their responses to different water pricing scenarios was built in order to analyse the results.

The differences in the demand for water can be explained by structural parameters (crop plans, irrigation methods, farm size etc.). We observe that for all the regions, when the price of water is low, the demand is not affected. Only when water reaches the higher prices does its demand become responsive, namely it drops.

In all regions farmers responded to the new water policies by modifying their farming strategies and cultivating less water demanding crops. They either substituted the crops which had a high demand for water with less demanding and even dry crops, or they adopted crops which could be watered using new irrigation technologies (i.e. drips irrigation, new water management practices or cropping techniques). In each of the regions, farmers applied different strategies depending on their main crops. In the Pella region, where the reduction of water consumption depends largely on the perennial fruit trees, the farmers' alternative solutions are limited as understandably, they are not willing to substitute their high value crops. In the Larissa region, on the other hand, where cotton, which is under CAP control, is the main crop and farmers readily change their production plans adopting non irrigated crops which are also controlled by CAP. Lastly, in the Xanthi region, the reduction of water consumption is not dependent on substituting tobacco which is not only the basic crop but also the main source of the economic viability of the area. Another important factor, which must be considered, is that in all the regions, there is a small number of available crops which are cultivated.

It can be clearly seen that the impact which the new water policies have had on all the irrigated regions is a substantial reduction in farm income. Farmers responded to price increases by reducing water consumption through changes in their production plans. They were forced to introduce less profitable crops as substitutes to the more lucrative water-intensive ones, whose effect was to significantly decrease farmers' earnings. In the Pella region, the reduction in farm income came to 23%, in Larissa 20% and in Xanthi 24% when the water price reached the level of 15 eurocents. The relative disparity in the percentages stated above can be explained by the different crop plans. Xanthi and Pella, for instance, whose main crops, tobacco and fruit trees respectively, form the basis of each region's agricultural economy are much more limited in their ability to completely change their crop plans.

Employment is also affected by these results. When water consumption is decreased as a result of substituting the water demanding crops with less demanding or even dry crops, there is a gradual but definite reduction in employment. In Pella, this reduction came to 18%, in Larissa 27.5%, and in Xanthi 14.4% when water prices peaked at fifteen eurocents. Increases in the price of water in the short-term, causes a severe reduction in farm labour input as a consequence of reduced water consumption through major changes in the crop plans. This implies that water intensive crops will be replaced by less demanding and more mechanised crops.

It should be stated that this chain of events does have a positive impact on the environment by reducing the amount of non-point chemical pollution of agriculture. Namely, an increase in water prices leads to a significant reduction in fertilizer use through changes to the crop plans. Obviously, as farmers attempt to save money by adopting less productive crops in order to cut down on water consumption, fertilizer use also decreases.

Extending the model on a long-term basis, we are able to reach further conclusions which can prove useful to policy makers. More specifically, we applied our model to the three selected regions under four different scenarios: a) World Markets, b) Global Sustainability, c) Provincial Enterprise, d) Local Stewardship. The results showed that an increase in the price of water has the same effect as that observed in the status quo scenario (Agenda 2000) analysed above. In all three regions, increasing water prices, decreases water consumption for all the scenarios.

In addition, increased water prices are accompanied by reductions in both farm income and employment. However, in the Provincial Enterprise and Local Stewardship scenarios, this is not quite the case. In both these situations, an increase in the price of water initially has the effect of increasing farm income, which then declines. Furthermore, in the Local Stewardship scenario, an increase in the price of water also has a positive impact on farm employment. The World Markets Scenario, however, was found to have a strong negative impact on both farm income and employment when water prices increased, in all the irrigated regions studied. The reasons for these peculiar results are not clear but they do illustrate the importance of taking the locally specific nature of needs, costs, and priorities into consideration. We are therefore, led to conclude that in certain cases, if the water pricing policy is applied on its own, it can have particularly negative results for farmers.

Focusing on the results of this research, we stress the fact that water pricing, as a single instrument for the control of water use is not a valid means of significantly reducing agricultural water consumption. This is because consumption only falls when prices reach such a high level that they have an extremely negative effect on both farm income and agricultural employment.

In sum, if water pricing is selected as a policy tool, it will result in at least three unfortunate consequences for the agricultural sector. Firstly, although the demand for water will decrease, farm income will also decrease. Needless to say, the impact of this on rural areas, which are dependent on irrigated agriculture will be catastrophic. Secondly, when water consumption is reduced through the measure of substituting high water-demanding crops (cotton, sugar beets, tobacco, maize) with those needing less water, a significant loss of employment will result both directly on the farms themselves and indirectly on the various processing facilities. Thirdly, there will be a decline in the selection of crops available for farming, which will have serious repercussions on the landscape and biodiversity. There will be fewer alternatives, as well as greater technical and economic vulnerability of the agricultural sector.

Nevertheless, in order for there to be a reduction in the consumption of irrigated water, we propose a sufficient water pricing policy in combination with the adoption of new irrigation methods and state-of-the-art technologies, which take into consideration the particular characteristics of each region (structural factors, agronomic conditions, financial constraints) and is in accordance with the water framework directive and the national water policy. Accompanying measures which help reduce and/or use irrigated water more efficiently can also be introduced: regulatory policies such as water metering, licenses and time-limited abstraction permits; as well as the promotion of appropriate technologies through the provision of advice, training and demonstrations of best practice.

Although the present study has not included an analysis on the impact of "full cost recovery" prices, it is generally assumed that this would prompt a considerable reduction in the use of irrigation water and would significantly limit investments in new schemes in the future. At the same time, clearly there is scope for improving existing irrigation technology without affecting the choice of crops. A more detailed analysis could help to set priorities for investments in irrigation and associated rural infrastructure, in the coming years. Moreover, Member States have an obligation to exercise detailed and thorough environmental scrutiny through their local, regional and national appraisal systems, in order to identify any potential negative environmental impacts and to take appropriate action. It is our fervent belief that apart from being interesting, these three areas constitute important points for further research in the future.

6. APPENDICES

1. Some characteristics of the 3 irrigated areas

	PELLA	LARISSA	XANTHI
Number of holdings	19,694	28,386	9,564
▪ less than 5 ha	14,731	21,233	7,269
▪ 5 - 10 ha	2,777	4,541	1,434
▪ more than 10	2,186	2,612	861
UAA (ha)	75,100	199.015,0	42.209,0
Farm Size (ha /per holding)	3.8	6.6	3.9
Family Members	41,166	50,459	19,382
Permanent Workers	274	759	274
Seasonal Workers	51,323	51,738	25,300
Family size (members/ per holding)	2.1	1.8	2.0
Tractors, double axis	14,041	13,639	3,245
Tractors, Singe Axis	689	382	24
Harvesters, threshers and mowers	130	97	60

2. Socio economic data and production plans of the clusters of irrigated area of Pella

PELLA	Total	Cluster 1- Small farms	Cluster 2- Medium farms	Cluster 3- Large farms
Number of holdings	25	14	7	4
Farm Size Average	3.6	1.8	6.2	15.3
Family Members	71	51	19	11
Permanent Workers	2	0	0	2
Seasonal Workers	88	29	21	38
Family size	2.8	3.6	2.7	2.8
Tractors, double axis	32	15	9	7
Tractors, Singe Axis	21	10	7	4
Harvesters, threshers and mowers	16	6	6	4
Irrigation technology methods				
▪ Gravity	✓	✓	✓	✓
▪ Pressure	✓	✓	✓	
Irrigation methods				
▪ Surface irrigation	✓	✓	✓	✓
▪ Sprinkler irrigation	✓		✓	
▪ Reel/Gun	✓	✓	✓	✓
▪ Drips irrigation	✓	✓	✓	
Farm plan (%)				
WHEAT	8,9	10,2	8,2	8,3
BARLEY	0,6	2,0	0,0	0,0
CORN	6,0	4,1	4,3	8,4
ALFALFA	0,9	1,3	1,8	0,0
COTTON	26,8	19,9	28,5	30,9
SUGAR BEET	25,6	18,7	27,2	29,9
TOMATO	5,0	0,0	2,8	9,8
PEACHES	22,0	32,3	25,6	12,6
APPLES	3,1	8,9	0,9	0,0
PEARS	1,1	2,7	0,8	0,0

3. Socio economic data and production plans of the clusters in irrigated area of Larissa

LARISSA	Total	Cluster 1- Small farms	Cluster 2- Medium farms	Cluster 3- Large farms
Number of holdings	25	12	8	5
Farm Size Average	6.4	2.6	9.2	31.2
Family Members	61	32	16	13
Permanent Workers	3	0	0	3
Seasonal Workers	52	18	14	20
Family size	2.4	2.7	2.0	2.6
Tractors, double axis	35	13	13	9
Tractors, Singe Axis	3	0	1	2
Harvesters, threshers and mowers	6	1	2	3
Irrigation technology methods				
▪ Gravity	✓	✓	✓	
▪ Pressure	✓	✓	✓	✓
Irrigation methods				
▪ Surface irrigation	✓	✓	✓	
▪ Sprinkler irrigation	✓	✓	✓	✓
▪ Reel/Gun	✓	✓	✓	✓
▪ Drips irrigation	✓		✓	✓
Farm plan (%)				
SOFT WHEAT	7,2	14,5	7,2	2,3
BARLEY	6,9	15,1	9,9	0,0
CORN	3,4	10,4	1,0	0,0
ALFALFA	3,0	3,0	2,0	3,5
COTTON	38,1	28,8	39,9	43,4
SUGAR BEET	3,1	1,0	1,5	5,3
TOMATO	0,9	0,0	0,0	1,9
HARD WHEAT	37,4	27,2	38,4	43,6

4. Socio economic data and production plans of the clusters of irrigated area of Xanthi

XANTHI	Total	Cluster 1- Small farms	Cluster 2- Medium farms	Cluster 3- Large farms
Number of holdings	23	13	7	3
Farm Size Average	3.8	1.8	6.0	18.5
Family Members	58	35	15	8
Permanent Workers	1	0	0	1
Seasonal Workers	90	39	33	18
Family size	2.5	2.7	2.1	2.7
Tractors, double axis	25	12	8	5
Tractors, Singe Axis	1	0	0	1
Harvesters, threshers and mowers	4	1	1	2
Irrigation technology methods				
▪ Gravity	✓	✓	✓	✓
▪ Pressure	✓			
Irrigation methods				
▪ Surface irrigation	✓	✓	✓	✓
▪ Sprinkler irrigation	✓		✓	
▪ Reel/Gun	✓	✓	✓	✓
▪ Drips irrigation	✓	✓	✓	
Farm plan (%)				
SOFT WHEAT	12,0	10,9	11,5	13,1
BARLEY	1,6	2,9	3,0	0,0
CORN	32,8	30,9	31,4	35,0
ALFALFA	9,6	18,0	16,0	0,0
TOBACCO	7,8	16,7	10,0	0,0
COTTON	14,6	7,0	12,1	21,5
SUGAR BEET	2,1	0,0	2,9	3,3
TOMATO	1,9	0,0	0,4	4,1
HARD WHEAT	17,5	13,7	12,7	23,0

9.

The case of Italy

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Vittorio Gallerani coordinated the research. Davide Viaggi wrote sections 2 and 4; Meri Raggi wrote sections 5.3, 5.4 and 5.5; Guido Maria Bazzani wrote section 3 and 5.1; Fabio Bartolini wrote section 5.2. Sections 1 and 6 were the joint effort of all the authors.

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1. BACKGROUND

Italy is characterised by very varied climatic and environmental conditions. A Mediterranean climate prevails, with cold wet winters and hot dry summers. Rainfall varies from less than

600 mm/year to more than 1200 mm/year, rising to over 2000-3000 mm/year in some areas. The current potential volume of water resources is around 110 billion m^3/year, of which only 52 billion m^3 are actually available (IRSA-CNR, 1999; ISTAT, 1991; 2000; 2001).

Agriculture accounts for about 50% of total water use. In spite of the increased irrigated surface area, the use of water in agriculture decreased in relative and absolute terms during the 1990s, due to the concurrent effects of improved irrigation technology and shortages of water during this period (with frequent droughts during the summer, often leading to a halt in water distribution). The CAP reforms may have played a role in the changing pattern of water use, albeit according to very different mechanisms in different farming systems. According to forecasts, future water requirements in agriculture are expected to stabilise around the present level of consumption (Massarutto, 2001).

Irrigated agriculture accounts for about 27% of usable farmland, 30% of farms and about 50% of total agricultural production. Around 60% of Italian agricultural exports are produced by irrigated agricultural methods (Leone, 1997; Bazzani et al., 2003a; 2003b).

Irrigation varies considerably across Italy, in terms of production systems, water availability and tariff systems. Traditionally, irrigation has been highly developed in the North, due to high water availability. However, its role is particularly important in the South, where irrigation is a necessary prerequisite for agricultural production based on high value-added crops. Water imbalances and droughts have become increasingly more frequent in the last decade, particularly during the summer in the South of Italy.

The main agricultural systems based on irrigation are annual crops (particularly maize and vegetables), fruit (oranges and other citrus fruits, peaches, apples, pears and kiwis), fodder crops (such as alfalfa). A very peculiar water using crop is rice, widely cultivated in some areas of Northern Italy, characterised by the high use of water due to submersion. The main irrigated sectors (vegetables and fruit) are those providing the highest value added per hectare, using more labour per hectare and showing the best trend in production (INEA, 2000). Irrigation is also important for guaranteeing the quality of production and, hence, it is a strategic factor affecting the overall strategy of most of Italian agriculture (INEA, 2000).

Water is generally distributed over the irrigated surface using sprinklers or mobile rain guns; however, irrigation techniques have undergone important changes over the last few decades, with the diffusion of micro-irrigation. Current research now has to take into account even more efficient irrigation techniques, such as underground irrigation, remote sensors for water monitoring, computer technology, water recycling, improved crops resistant to water stress and capable of using water more efficiently.

The water distribution system in Italy relies mainly on "Reclamation and Irrigation Boards" (RIBs) (Consorzi di Bonifica e Irrigazione): these are public bodies - managed as associations of landowners - that control land reclamation and the distribution of water over a certain area. RIBs distribute about 90% of the water used for irrigation (ANBI, 1992; 1998; AA.VV., 2001).

Most of the distribution system is based on open canals. New water distribution systems more frequently adopt pressure pipes. Average water cost at the farm is about 36 euro/ha, but actual tariffs range from 2 to 355 euro/ha. The tariff system is usually based on the distribution of running costs on an area basis. Only a small share of total irrigated area water is measured and paid for through volumetric pricing.

The implementation of the water framework directive (WFD) (60/2000) regarding irrigation and agricultural policy, has received relatively little attention in Italy up until recently. Although a number of documents about water and irrigation do exist, they are heterogeneous, poorly updated and methodologically varied (INEA, 2000; Massarutto, 2001).In theory, the water management principles proposed by the WFD (WATECO, 2002; Massarutto, 2002) could bring about major changes in irrigation management.

The objective of this paper is to provide an analysis of the economic, social and environmental sustainability of irrigated agriculture in Italy within the context of the post-Agenda 2000 CAP Reform and of the Water Framework Directive (EEC 2000/60). The research was carried out within the framework of the WADI project.

2. CASE STUDY DESCRIPTION AND CLUSTERS DEFINITION

The chosen case studies intend to cover some of the main agricultural systems in Italy where irrigation is a relevant feature. The methodology has been applied to five irrigated agricultural systems. For the purposes of this study, an agricultural system is taken to be a form of farming defined by a given crop combination and located in a given river basin. The river basin is identified with the RIB to which the system belongs. According to this definition, the irrigated system represents a way of farming, in a homogenous territory, which is combined with others in different proportions depending on the specific area.

The irrigated farming systems for which models have been created are as follows (Figure 1):

- Cereal system: Mantua – Lombardy – Northern Italy (RIB Fossa di Pozzolo);
- Rice system: Ferrara – Emilia-Romagna – Northern Italy (RIB I Circondario Polesine di Ferrara);
- Fruit system: Ravenna – Emilia-Romagna – Northern Italy (RIB Romagna Occidentale);
- Vegetables system: Foggia – Apulia – Southern Italy (RIB Capitanata);
- Citrus system: Syracuse – Sicily – Southern Italy (RIB Piana di Catania).

Figure 9.1. The farming systems modelled

1. *Cereal system*
2. *Rice system*
3. *Fruit system*
4. *Vegetable system*
5. *Citrus system*

The main features of the study areas, and the way in which case studies have been selected, are illustrated in tables 9.1 and 9.2.

Table 9.1. Main crops cultivated in the five study areas

	Farm system				
	Cereal Lombardy	**Rice Emilia-Romagna**	**Fruit Emilia-Romagna**	**Vegetables Apulia**	**Citrus Sicily**
Crops					
▪ Durum wheat				O	
▪ Soft wheat	O		O		
▪ Maize	X	X			
▪ Soya been	X	X			
▪ Sugar beet	X	X	O		
▪ Fallow	O	O			
▪ Melons	O				
▪ Water melons	O				
▪ Tomatoes		O		O	
▪ Rice		X			
▪ Peaches			X		
▪ Nectarines			X		
▪ Plums			O		
▪ Apricots			O		
▪ Apples			O		
▪ Pears			O		
▪ Kiwi fruit			O		
▪ Wine grapes			X		
▪ Broccoli				X	
▪ Asparagus				X	
▪ Artichokes				X	
▪ Citrus fruit					X

X = Main crops; O = secondary crops

The cereal system case-study focuses on the RIB Fossa di Pozzolo (Mantua), in the South-Eastern part of Lombardy (Northern Italy). It is characterised by the relative ready availability of water. It represents a variety of extensive farming, traditionally based on average to high water use and benefiting from considerable public support. The sample includes 26 farms belonging to one farm type.

The rice system case-study concerns an area close to the Po delta, in the RIB I Circondario Polesine di Ferrara (Ferrara – Emilia-Romagna - Northern Italy).Water is readily available, but there are also strong agronomic constraints due to peaty soils that require the cultivation of rice, over at least half of the area, in order to maintain those soil characteristics compatible with farming. For this reason, such a system is representative of the vulnerability of farming in high water-consuming, but economically marginal, areas. A sample of 86 farms was collected and sub-divided into two farm types, each characterised by a different soil type (peaty, non-peaty).

The case-study featuring the fruit system is located in the eastern part of Emilia-Romagna (Northern Italy) in the RIB Romagna Occidentale (Western Romagna), in the province of Ravenna. Farming mainly involves the cultivation of peaches, wine grapes and kiwi fruit. The fruit system is traditionally considered one of the most profitable and strong farming systems in Italy. In fact, it is a system producing high value added, it is backed by a strong marketing organisation, and mostly involves co-operative working. Altogether, 4 farm types were modeled out of a sample of 1479 farms, differing in farm size, household structure and management style, which resulted in a different crop mix.

Table 9.2. Main features of the five study areas

	Farm system				
	Cereal Lombardy	**Rice Emilia-Romagna**	**Fruit Emilia-Romagna**	**Vegetables Apulia**	**Citrus Sicily**
Water supply	Po river	Po river	Emilia-Romagna Canal	Dams, Ofanto river, private wells	Dams, Simeto river, private wells
Water distribution system	Open canals	Open canals	Pressure pipes +Open canals	Pressure pipes	Pressure pipes
Irrigation system	Mobile wings, automatic sprinkler	Flood system, infiltration	Drip irrigation	Drip irrigation	Drip irrigation, sprinkler
Water price	0.09 euro/m^3	0.02 euro/m^3	0.15 euro/m^3	0.09 euro/m^3	0.18 euro/m^3
Prevailing tariff system	Surface based	Volumetric	Volumetric	Volumetric	Volumetric
Agricultural surface in the RIB (ha)	48137	91085	193359	143000	98000
Agricultural surface of the system considered (ha)	27919	11582	21675	25740	14700
Area in the sample (ha)	1105	6093	6086	913	187
Number of farms in the sample	26	86	1479	120	16
Average farm size in the sample (ha)	42.5	70.8	4.1	7.6	11.6
Methodology for the identification of farm types	Interviews with local experts	Cluster analysis and interviews with local experts	Cluster analysis	Cluster analysis	Data from previous surveys and interviews with local experts
Number of typologies modelled	1	2	4	2	2

The case-study of the vegetable system is located in the South of Italy (Apulia), in the RIB Capitanata (Province of Foggia). It features a combination of high-income tomatoes (for canning), and highly-subsidised traditional crops such as non-irrigated durum wheat. The development of high value-added crops, such as tomatoes and other vegetables, is counterbalanced by a high environmental impact, and is dependent upon the sufficient availability of water. The sample consists of 120 farms sub-divided into 2 farm types, one based on tomato-durum wheat and the other cultivating a wider range of vegetables.

Finally, the citrus-fruit case study involves a highly-specialised, intensive system based in Southern Italy (RIB Piana di Catania, province of Syracuse, Sicily). It is representative of the rich, but fragile, agricultural systems of certain Mediterranean areas, and is heavily dependent upon water availability (farming is not possible without irrigation) and with a very level of water consumption, located in a context characterised by significant social problems and a high level of unemployment. The citrus-fruit farming system is highly characteristic of the area in question, where oranges constitute the main crop. The sample included 16 farms, sub-divided into 2 farm types, differing basically according to farm size (3 ha vs. 15 ha).

The definition of farm types consisted of the following steps:

- a preliminary analysis was carried out using data from 2000 census and FADN, in order to support the definition of the relevant farming systems and, at a later stage, to allow extrapolation to the regional level;
- available data sets related to local farms and data from previous research were collected;
- cluster analysis of these data sets was conducted in order to identify farm types for rice, vegetables and fruit;
- a limited number of interviews of local experts were used in order to support cluster analysis (particularly for rice) and to define relevant farm types in the case of cereals and citrus fruit.

Following the definition of farm types, primary data required for model calibration were collected on a sample of farms.

Each cluster has been modelled separately and then aggregated.

3. METHODOLOGY

The farm types were modelled according to the agreed methodology (see the chapter on methodology in this book). In each case, a mathematical programming model was built using the MAUT approach[6].

The models used were mostly linear, but in some cases integer programming was adopted in order to take into account discontinuous behaviour, such as changes in irrigation equipment[7].

[6] Developed by Sumpsi et al. (1996), Berbel and Rodríguez-Ocaña (1998), Berbel and Gomez-Limon (2000).

[7] Further details about the structure of the models are given in chapter 5. See also Bazzani et al. (2003c; 2004a; 2004b; 2004c). Additional technical insights into the setting up of the linear programming model, the MAUT application and its use in estimating the water demand curve, are derived from Edwards (1977), Harper and Eastmen (1980), Howitt et al. (1980), Cary and Holmes (1982), Farmer (1987), Romero and Rehman (1989), Bogges et al. (1993), Moore et al. (1994), Dinar and Subramanian (1997), Varela-Ortega et al. (1998), Dosi and Easter (2000), Dono and Severini (2001), Gómez-Limón et al. (2002).

Models were calibrated using primary data collected from the surveyed farms (see the samples in table 9.1) and validated against the actual behaviour of farms seen as a combination of farming activities (rotation and irrigation choices).

Both short-term and long-term models were developed. The methodology and the results illustrated in this paper only refer to long-term models.

A summary of the features of the models developed is given in table 9.3.

The average farm size varies considerably from one case to the other, showing the variety of farm structure both within each farming system and between different systems.

Most of the farm models displayed more than one objective, in particular, a combination of income and some variety of labour minimisation (total labour, external labour or family labour). Profit is only a significant objective in the case of cluster 1 of the vegetable system, characterised by those farms with low availability of labour, aiming to produce income by restricting the involvement of family labour. Risk does not often appear to be a relevant objective, mostly because some risk-related choices are already imposed by model constraints (for example rotations). In one case, risk-averse behaviour is represented through an indicator of crop differentiation. Only in two clusters, both related to the fruit system, does the MAUT yield only one important objective, that is, net income.

Constraints include standard constraints such as land, labour, commercial constraints and rotations. Labour constraints have been constructed by period (monthly or bi-monthly, depending on the case study).

Table 9.3 Main features of the models

	Farm system										
	Cereals Lombardy	**Rice Emilia-Romagna**		**Fruit Emilia-Romagna**				**Vegetables Apulia**		**Citrus Fruit Sicily**	
Model	1	1	2	1	2	3	4	1	2	1	2
Average farm size (ha)	42.5	100	100	1.03	5.01	10.79	17.31	7.52	7.71	3	15
Objectives											
▪ Profit								0.57			
▪ Income	0.87	0.84	0.82	0.95	0.98	0.35	0.82		0.9	0.83	0.66
▪ External labour	0.13					0.6					
▪ Total labour		0.16	0.18					0.13	0.1		0.34
▪ Family labour				0.05	0.02	0.01	0.18			0.17	
▪ Crop differentiation								0.3			
Constraints											
▪ Land	X	X	X	X	X	X	X	X	X	X	X
▪ Labour	X	X	X	X	X	X	X	X	X	X	X
▪ Marketing	X	X	X	X	X	X	X	X	X		
▪ Rotations	X	X	X	X	X	X	X	X	X		
▪ Crop differentiation				X	X	X	X				
Cluster weight in 2001	1.000	0.528	0.472	0.307	0.308	0.322	0.063	0.502	0.498	0.575	0.425
Forecasted weight WM	1.000	0.198	0.802	0.285	0.216	0.418	0.081	0.253	0.747	0.362	0.638
Forecasted weight GS	1.000	0.340	0.660	0.300	0.277	0.354	0.069	0.452	0.548	0.532	0.468
Forecasted weight PE	1.000	0.387	0.613	0.300	0.277	0.354	0.069	0.452	0.548	0.532	0.468
Forecasted weight LS	1.000	0.481	0.519	0.307	0.308	0.322	0.063	0.502	0.498	0.575	0.425

Once constructed and validated against the Agenda 2000 situation in 2001, the models were fed with the data coming from the scenario analysis. Scenarios have been developed following the general framework (see the respective chapter in this book), with reference to the Italian situation, particularly as far as specific environmental conditions, productive features, quality strategy and self-sufficiency issues are concerned.

Prevailing values and the level of governance are recognised as the two main driving forces behind possible futures[8]. Their various combinations give four main scenarios:

- world markets (wm);
- global sustainability (gs);
- provincial enterprise (pe);
- local stewardship (ls).

World markets describes a scenario characterised by a high degree of liberalisation, where decisions are taken through market mechanisms at the global level. In the provincial agriculture scenario, choices are guided by markets, but they work on a regional scale. In the other two scenarios, decisions are taken on the basis of community values, which may work at the global (global sustainability) or local (local community) levels (Berkhout et al., 1998 Kroll and Treyer 2001; Berbel et al., 2002).Agenda 2000, as implemented in 2001, has been taken as a benchmark for comparing scenarios.

The time horizon for scenario definition was taken to be 2010. Firstly storylines were developed, followed by the quantitative definition of prices and other parameters. The prices and technical coefficient adopted in different scenarios were calculated with the aid of experts in the field. Altogether, more than 100 parameters were defined, combining consistent futures of agricultural and water policy (OECD, 1999).

Altogether, by crossing farm types with scenarios, 55 long-term models were produced. For each of them, results have been parametrised on water price, thus giving the water demand curve and the trend of all indicators as a function of water prices. The indicators illustrated in this paper were calculated using the most likely price of water for each scenario. The changes in the water prices used are given in table 9.4 below.

Table 9.4. Scenarios of water prices at the farm gate (in 2001 = 100)

	World Agricultural Markets	Global Agricultural Sustainability	Provincial Agriculture	Local Community Agriculture
Cereals	120	130	110	110
Rice	110	120	100	95
Fruit	130	140	120	140
Vegetables	140	160	130	170
Citrus Fruit	140	160	130	170

The full set of selected WADI indicators (see the chapter on methodology) were calculated as a result of the modelling exercise (EC Commission, 2000; OECD, 2001).

Once the results had been calculated for each model, they were aggregated for each area. Only aggregated results - calculated as the weighted sum of the results of each cluster in each study

[8] Drivers such as climate change have not be considered. Technology is considered as a dependent variable.

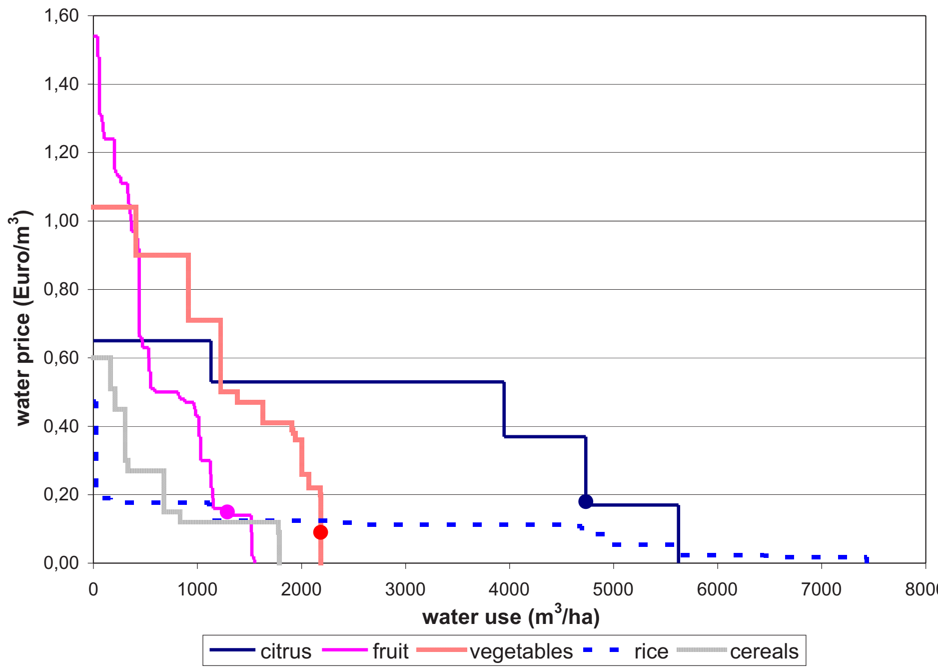
area - are illustrated in this paper. Weighting was produced on the basis of existing statistics for farm types, using the total usable agricultural surface of the farms belonging to each farm type as the weighting factor. When the scenario identified possible variations over time in the composition of farm types (e.g. the enlargement of big farms and the reduction of the number of small ones), the weights were adjusted accordingly. As a result, aggregation weights vary from one scenario to the next. All final results are expressed as an average of total usable surface per hectare of the farming system in question.

The models were developed using GAMS as the optimisation software. In the case of fruit farming and cereals, an interface was developed (DSIRR) using Visual Basic in order to allow for the more user-friendly construction and use of the models.

4. THE IMPACT OF WATER DEMAND AND PRICING ON THE AGRICULTURAL SYSTEM

The surface of the RIBs in question amounts to 573,000 ha (almost 5% of total usable Italian farmland). The variety of irrigated systems is well illustrated by the comparison of the aggregated demand curves of the five study areas, using present (2001) prices and CAP payments (figure 9.2).

Figure 9.2. Aggregate demand curves for the five study areas



The strong differentiation is made evident by the shape of the curves. The two extremes are represented by the rice system and the fruit system. The rice system uses a considerable amount of water at no cost, and shows very high reactivity to price increases. The fruit system, on the contrary, requires a relatively small amount of water, but demand remains very stable as water prices rise.

The citrus system uses a relatively large amount of water, due to the climatic characteristics of the area involved, and water demand decreases slightly up to a price three times the present one;above such a price, demand falls sharply due to the lack of real alternatives to irrigated citrus.

The vegetable system shows a relatively rigid demand curve, due to its high profitability.

Finally, the cereal system has a rather varied curve, with relatively rigid behaviour at low prices, followed by a very reactive area which is then followed, once again, by a more stable area of the demand curve.

The variety in performance of the different systems is represented by the sustainability indicators in the baseline (Agenda 2000) scenario (table 9.5.).

The socio-economic indicators are a good representation of the low profitability of the agricultural sector as a whole, and of its difficulty in providing remuneration for all productive means.

In the Agenda 2000 scenario, only two out of five farming systems show a profit: cereals and vegetables. The rice system, which had been highly profitable in the past, saw a reduction in income leading to a slight loss, during the 1990s. The fruit system showed a slight loss due to the high cost of labour in the area. Nevertheless, it can be considered as an indicator of the satisfactory remuneration of productive factors. Citrus fruit made a significant loss, the result of the high labour costs, while farms actually accepted the under-remuneration of farm labour in order to maintain net income levels

Table 9.5. Main performance indicators of the five systems

		Economic Balance			**Social Impact**		**Landscape and Biodiversity**		**Water use**	**Nutrient and Pollutants**		
		Profit	**Contribution to GDP**	**Public support**	**Farm employment**	**Seasonality**	**Genetic diversity**	**Soil cover**	**Water use**	**Nitrogen balance**	**Pesticide risk**	**Energy balance**
	Crop system	€/ha	€/ha	€/ha	hours/ha	index	index	index	m³/ha	Kg/ha	index	MJ/ha
Agenda 2000	cereals	91.23	1051.64	162.85	43	0.15	6.00	0.49	834	-30	4757	-84264
	rice	-16.60	1092.24	285.29	27	0.12	4.47	0.46	7435	-42	493	-97015
	fruit	-297.18	3084.47	70.34	239	0.05	9.01	0.78	1287	67	30995	-27468
	vegetables	489.40	2601.81	321.18	91	0.01	3.50	0.53	2185	72	95518	-103824
	citrus	-1802.95	3410.33	0.00	532	0.13	1.00	1.00	4733	174	48725	-23862

In spite of these results, all systems made a significant contribution to GDP. In fact, the citrus fruit system was the one that made the highest agricultural contribution to GDP, with more than 3400 euro/ha, a remarkable level of value-added for a farming system. This was followed by the fruit system. The two Northern annual crop systems (cereal and rice) made the lowest contribution to GDP, while the vegetable system's performance was somewhere in between.

Public support somehow showed an opposite trend. It was higher for the vegetable system than for rice and cereals, due mainly to CAP payments. It was particularly high in the vegetable system due to support for durum wheat - the main crop in the area - rotated with industrial tomato. Public support for fruit in general was very low (due to a residual part of the farm being cultivated with annual crops), and non-existent for citrus fruit.

Agricultural employment grows as the contribution to GDP increases. It is particularly high in the citrus fruit sector, followed by fruit and vegetables. It should be noted that the amount of labour over 500 hours/ha corresponds to about 1 labour unit every 4 hectares. Citrus, fruit and vegetables also have a strong impact on the food chain, both in terms of value added and employment. The amount of labour was very low for annual crops.

Seasonality is not an important issue, with the partial exception of certain types of extensive farm systems (cereals, rice) that also involve the cultivation of a certain amount of vegetables, and the citrus system.

The most complex system, in terms of the number of species cultivated, is the fruit system, followed by the cereal system. The simplest one, on the other hand, is the citrus system with basically one crop only. Nevertheless, this is not an indicator of low landscape quality. In fact, the citrus system is a traditionally important feature of the typical intensive tree landscape of the more fertile areas of Sicily (and of the Mediterranean in general), and the focus on citrus fruit is a much-appreciated, distinguishing feature of such areas.

Water use reaches its peak in the case of the rice system, due to the practice of submersion. A very high level of consumption is also seen in the case of citrus fruit, chiefly due to the climate in southern Italy. The amount of water used drops as one shifts to vegetables, fruit and cereals.

It is clear from these figures that the best performance, in terms of value added per unit of water consumed, is that of the fruit system, while the worst is that of rice.

The anthropic nitrogen balance is negative (output higher than input) in the case of the more extensive crops, while its use intensifies with vegetables and fruit, and reaches its peak with citrus fruit.

As for pesticides, the worst value is that seen in the case of vegetables, followed by citrus fruit and other fruit. Relatively low values are seen in the cases of rice and cereals.

The energy balance is always negative, thus showing that the system produces more output than inputs. The highest values are those of annual crops, and in particular vegetables, while for fruit and citrus, the output (fixed solar energy) is to a considerable extent compensated by higher energy input (fuel, machinery and materials).

Altogether, the data show the fragility of Italian farming systems and the trade-off between socio-economic indicators and environmental performance. This trade-off can also be seen to a significant degree in the case of water as well. This highlights the need for a more careful balance of water conservation and rural development objectives.

5. Results For Each Scenario: Aggregated Water Demand And Scenario Impact

5.1. Cereals - Lombardy

The cereal system is probably the most commonly found one in Italy, and also the most important in terms of water consumption. It includes those crops accounting for the highest share of the country's total irrigated land area, such as maize and soya. The main crops cultivated within this system account for about 30% of total farmland in Northern Italy. The system is also connected to fodder crops for livestock farming (one of the main sources of income for local agriculture).

In socio-economic terms, this area is relatively wealthy (a GDP of 21,300 euro per capita),it is close to important industrialised areas (such as Milan), and agriculture provides increasingly less income and employment in the area (accounting for 6% of employment and 8.6% of GDP in the province of Mantua; 1.4% of employment and 1.5% of GDP in the Lombardy region as a whole the).

The demand curves for water vary considerably from one scenario to another (see figure 9.3).

The differences are particularly significant at low prices (generally comparable to present prices or lower). In fact, if we assume there is a shift from area to volumetric pricing, then the water tariff will be about 0.10-0.13 euro/m^3, thus bringing all scenarios above the first step of the demand curve.

In this sense, a pricing policy may be expected to be effective in this area. However, it requires a change in the distribution system, with additional costs for measurement and monitoring which would lead in turn, to even higher prices.

It should also be noted that three scenarios out of four are characterized by a very low level of water consumption regardless of the price (which may even be zero). This is due to the fact that decreasing prices and/or increasing costs tend to cause the farming of some crops, such as sugar beet and soya, to shift from an irrigated to a rain-fed system. In such cases, there would probably be little need for a pricing policy, since the consumption of water would already be concentrated on the most profitable crops only.

Figure 9.3. Demand curves by scenario

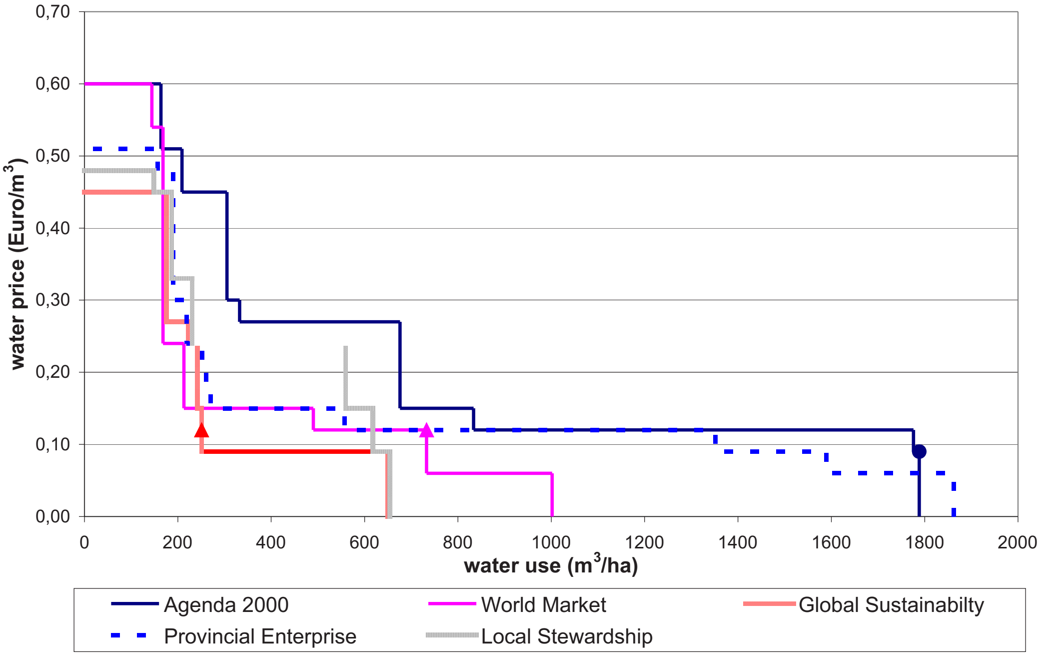


Table 9.6 shows the impact indicators per scenario, both in terms of absolute value and percentage variation.

Table 9.6. Impact indicators per scenario (absolute value and percentage variation from Agenda 2000)

		Economic Balance			Social Impact		Landscape and Biodiversity		Water use	Nutrient and Pollutants		
		Profit	**Farm contribution to GDP**	**Public support**	**Farm employment**	**Seasonality**	**Genetic diversity**	**Soil cover**	**Water use**	**Nitrogen balance**	**Pesticide risk**	**Energy balance**
	Scenario	€/ha	€/ha	€/ha	hours/ha	index	index	index	m^3/ha	Kg/ha	index	MJ/ha
cereals	World Market	-176.27 -293%	504.17 -52%	0.00 -100%	25 -42%	0.05 -67%	5.00 -17%	0.49 0%	490 -41%	-34 -12%	4797 1%	-89855 -7%
	Global sustainability	-141.01 -255%	675.48 -36%	237.62 46%	25 -41%	0.00 -100%	5.00 -17%	0.48 -2%	242 -71%	-27 9%	4241 -11%	-62473 26%
	Provincial Enterprise	25.67 -72%	871.29 -17%	172.46 6%	29 -32%	0.01 -93%	6.00 0%	0.49 0%	557 -33%	-33 -9%	4789 1%	-88769 -5%
	Local stewardship	-84.23 -192%	958.08 -9%	178.21 9%	31 -28%	0.00 -100%	6.00 0%	0.49 0%	618 -26%	-33 -9%	4787 1%	-88791 -5%

All scenarios yield economic results that are worse than Agenda 2000. World market and global sustainability give the worst economic results. Moreover, farm employment decreases strongly, with a reduction of up to 42% in the case of the world market. This reduction involves the expulsion of external labour from the farm, with the seasonality index falling to zero in most cases. The use of water varies strongly according to crop profitability, mainly as a function of public support and water price. The greatest reduction (-71%) is seen in the case of global sustainability, but the other scenarios would also witness a reduction of at least 30%.

Environmental indicators are basically stable across scenarios, with variations mostly limited within the 10% range.

On a regional scale, the economic impact of the various scenarios may be important in relation to agriculture, as the system is a widespread one. On the other hand, from a global economic and social point of view, the impact may be considerably less relevant. Labour is likely to shift to other sectors, at least in the medium term, as the area has very low unemployment (about 4%). In addition, the area is characterised by strong competition for resources among the different sectors. However, as agriculture is a traditionally important activity in the area, it would be socially desirable to maintain and defend it to some extent, even in the worst scenarios.

The most important positive effect of the scenarios is the fall in water consumption regardless of the scenario. The area used to be relatively rich in water, but water saving is becoming a crucial issue. Saving water in general may contribute towards increasing water availability in key periods, and for the most profitable crops (e.g. melons and water melons), in order to improve the efficient of water use.

Few significant environmental improvements have been made in this area, where the main problem remains that of nitrogen pollution from fertilisers (121 kg/ha per year) and manure. Pesticides have a comparatively less significant impact (6 kg/ha per year of active matter, 11 of total products).Moreover, the worst effects have already been dealt with over the last decades.

5.2. Rice - Emilia-Romagna

The rice system is a highly singular system (rice cultivation accounts for about 6,500 ha in the whole region), connected with the much more widespread cereal system (based on wheat, sugar beet and maize).

The area is not particularly rich compared to other areas of Northern Italy (a GDP of 18,300 euro per capita), and agriculture represents one of the main economic activities, one that is disadvantaged from several points of view. Aggregated indicators for the whole province only partially reveal the singularity and relevance of agriculture in this area (8.6% of employment and 7.4% of GDP in the province of Ferrara; 4.9% of employment and 3.5% of GDP in Emilia-Romagna as a whole).

Figure 9.4 shows the rice system's demand curves for water in the various different scenarios.

The demand curves vary considerably from one scenario to the next. The differences are particularly significant at low water prices than the actual ones. In addition, as the costs of water provision are relatively low in this area, a shift of a few eurocents may affect the overall profitability of rice cultivation.

In fact, even at zero price, shifting to the world market would mean a reduction in water use of around 60% compared with the present situation. In this area, even though the distributory system is based on open canals, there is already a system of water metering. This may facilitate the relatively simple implementation of further quantity-related water policies.

The issue in this particular area is that the aim of water policy is not just to reduce water consumption, but to encourage the optimal distribution of water, estimated at 5000 m^3/ha for environmental reasons. It is clear that the world market, or even global sustainability, would bring the quantity of water used to below such a threshold, even at zero price. If such a scenario arose, then environmental considerations could even encourage an increase in the use of water. In the other scenarios, a more precise regulatory setting could be devised. Nevertheless, a major increase in water prices (over and above present prices) does not appear either necessary or useful in environmental terms.

Figure 9.4. Demand curves by scenario

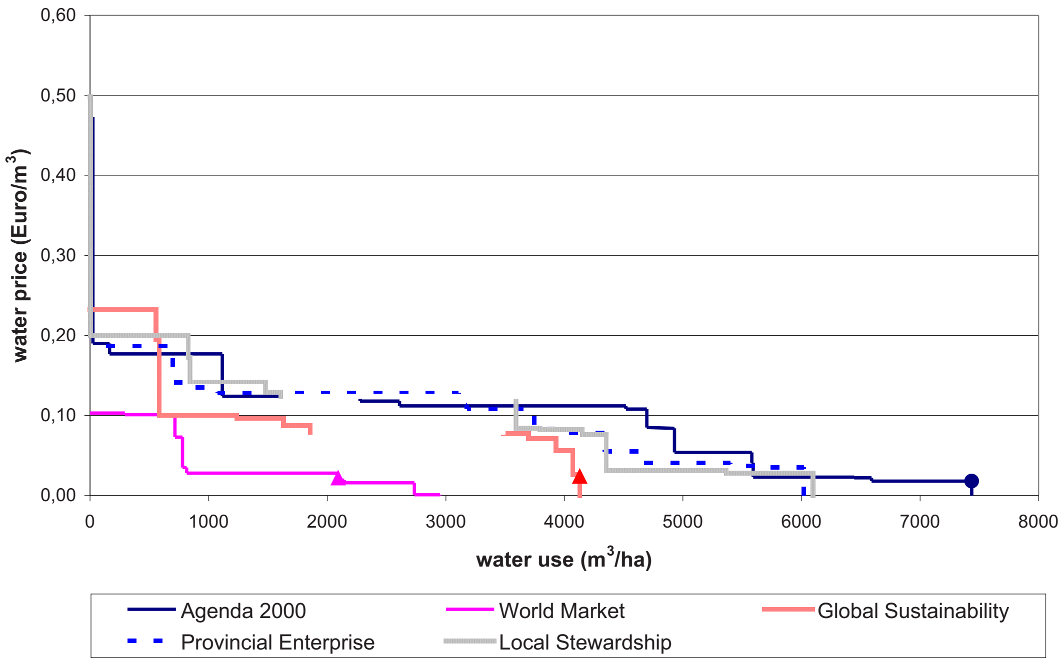


Table 9.7 shows the impact indicators by scenario, both in terms of absolute value and percentage variation.

Table 9.7. Impact indicators by scenario (absolute value and percentage variation from Agenda 2000)

		Economic Balance			Social Impact		Landscape and Biodiversity		Water use	Nutrient and Pollutants		
		Profit	**Farm contribution to GDP**	**Public support**	**Farm employment**	**Seasonality**	**Genetic diversity**	**Soil cover**	**Water use**	**Nitrogen balance**	**Pesticide risk**	**Energy balance**
	Scenario	€/ha	€/ha	€/ha	Hours/ha	index	index	index	m^3/ha	Kg/ha	index	MJ/ha
rice	World Market	-609.36 -3571%	355.49 -67%	0.00 -100%	11 -57%	0.07 -41%	2.40 -46%	0.38 -18%	2144 -71%	-40 3%	679 38%	-68239 30%
	Global sustainability	-307.87 -1755%	836.31 -23%	263.70 -8%	20 -23%	0.10 -11%	5.00 12%	0.47 1%	4130 -44%	-75 -81%	304 -38%	-72991 25%
	Provincial Enterprise	-72.81 -339%	1057.26 -3%	286.13 0%	23 -14%	0.12 -1%	4.61 3%	0.47 0%	6018 -19%	-61 -48%	470 -5%	-83247 14%
	Local stewardship	-80.86 -387%	1106.14 1%	198.67 -30%	23 -12%	0.13 9%	4.00 -11%	0.47 1%	6097 -18%	-32 22%	432 -12%	-79506 18%

The economic results are strongly affected by the hypothesis regarding public subsidies within each scenario, (especially subsidies for rice, but also for other COP crops). In particular, profits and GDP fall dramatically in the world market scenario. The percentage result is the worst among annual crop systems. In the world market scenario, profit is also strongly negative, making the cultivation of this particular area no longer profitable.

All scenarios show a reduction in the use of labour. This is not a particularly relevant feature, as the level of labour employed in this system is already very low.

Water use is also reduced, although it is not a particularly relevant issue in this area of Italy, as we have already mentioned. The environmental results for the various scenarios appear to be somewhat contradictory. Generally speaking, the strong percentage variations (plus or minus) are made less relevant by the absolute value of pollution, which is remarkably low on the whole.

The impact would strongly affect the area under analysis, with results depending largely on soil characteristics. The distinguishing factor of this area is that it consists largely of peaty soil situated below sea level, the land having been reclaimed during the last century. Peaty soils mean that at least half the surface is cultivated with rice, and hence there will be a limited capacity to adapt to changing scenarios, as a consequence of the inherent agronomic constraints. When this crop is no longer profitable, given that it is not possible to change the crop mix, then farmland may be gradually abandoned or part of the area may be reconverted to parkland (wetlands). In other words the rice system can only survive if provided with some form of public support; otherwise, it tends to be abandoned.

There could be considerable environmental benefits from abandoning cultivation in this area, which is characterised by relatively high pollution (90 kg/ha per year of nitrogen and 10 kg/ha per year of active matter of pesticides, 21 kg/ha per year of total products), but they would probably be much less important than other effects such as the problems of water control.

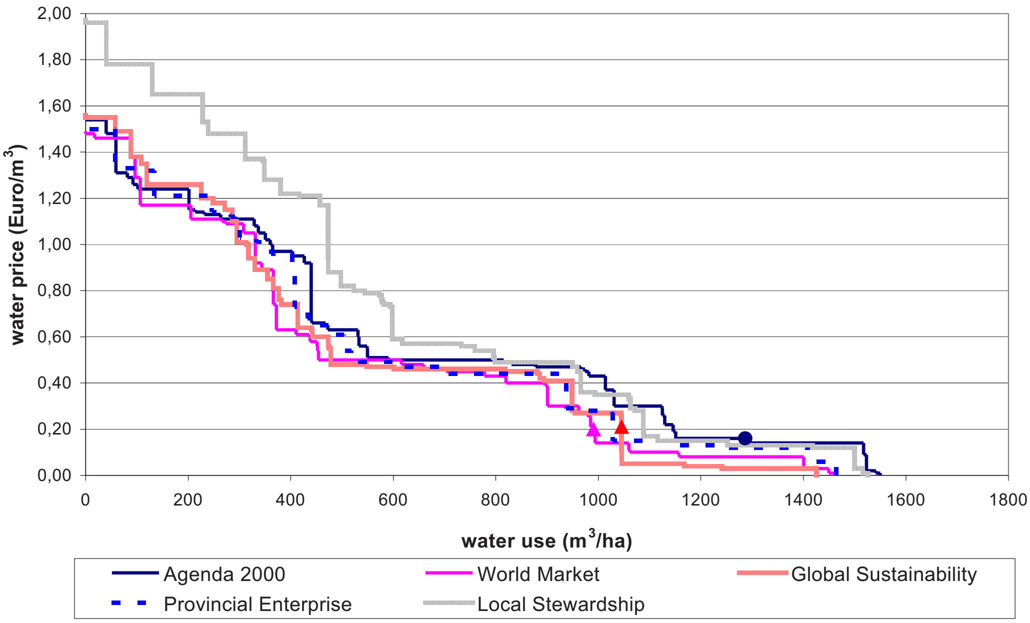
Even though the present farming system is based largely on subsidies, such subsidies are justified by the wide array of services that the system produces for society as a whole. The present system allows for the sustainability of farming in the area and its contribution to environmental sustainability as a sort of tacit by-product of agricultural activities. The most desirable scenario would involve a more explicit consideration of the actual role of the farming system in delivering public goods within the area, and a combination of CAP, rural development and water policy designed to respond to local social objectives. One possible result could be a major "re-naturalisation" of the area. Given the singularity of the area, this could also be acceptable as a local response to the world market scenario. The alternative is the progressive abandonment of land, starting with the worst soil.

5.3. Fruit - Emilia-Romagna

The fruit system accounts for only about 3% of total usable farmland in Northern Italy, but is one of the most important in terms of profitability. It is situated in a relatively rich context (GDP of 20,900 euro per capita), characterized by employment alternatives, where agriculture plays a relatively marginal role (6% of employment and 5% of GDP in the province of Ravenna; 4.9% of employment and 3.5% of GDP in Emilia-Romagna as a whole). Unemployment in the region stands at about 4%.

Figure 9.5 shows the demand curves for water for the fruit system according to the various different scenarios.

Figure 9.5. Demand curve by scenario



The demand curves are very close together, thus showing the substantial stability of the model for the various scenarios, as far as water use is concerned. The lower section of the demand curves in all scenarios shows the reaction to increasing water prices based on the abandonment of irrigation of secondary annual crops. This is already happening at present prices, which are above 0.15 euro/m^3. The following stage of the demand curve is rather rigid, and a twofold or threefold increase in the present price would be needed in order to produce a significant change in water consumption, due to the abandonment of the irrigation of wine grapes and then of other fruit, such as apricots. A pricing policy aimed at further reducing water consumption would only make sense above this threshold. As it is likely that the cost of water in the area would not justify such prices, a pricing policy would not be suitable even if a metering system were already working on a significant number of farms.

Table 9.8 shows the impact indicators by scenario, both in terms of absolute value and percentage variation.

Table 9.8. Impact indicators by scenario (absolute value and percentage variation from Agenda 2000).

		Economic Balance			Social Impact		Landscape and Biodiversity		Water use	Nutrient and Pollutants		
		Profit	**Farm contribution to GDP**	**Public support**	**Farm employment**	**Seasonality**	**Genetic diversity**	**Soil cover**	**Water use**	**Nitrogen balance**	**Pesticide risk**	**Energy balance**
	Scenario	€/ha	€/ha	€/ha	hours/ha	index	index	index	m^3/ha	Kg/ha	index	MJ/ha
fruit	World Market	-916.05	2044.58	0.00	185	0.00	8.23	0.72	991	65	23003	-29232
		-208%	-34%	-100%	-22%	-100%	-9%	-8%	-23%	-2%	-26%	-6%
	Global sustainability	-1026.21	2645.86	151.27	214	0.00	7.35	0.77	1045	64	24108	-9930
		-245%	-14%	115%	-10%	-100%	-19%	-1%	-19%	-5%	-22%	64%
	Provincial Enterprise	-687.73	2672.90	82.62	212	0.00	8.40	0.75	1028	67	25999	-28232
		-131%	-13%	17%	-11%	-96%	-7%	-4%	-20%	0%	-16%	-3%
	Local stewardship	-712.78	3485.91	79.25	229	0.00	10.27	0.75	1088	67	32277	-28066
		-139.85%	13%	13%	-4%	-100%	14%	-3%	-15%	0%	4%	-2%

The system is basically stable and able to match most of the scenarios without any major changes in the crop mix. The more significant changes concern profitability and the contribution to GDP resulting from price changes across scenarios. However, relatively significant changes in profit can be misleading: if farmers accept a certain degree of under-payment of family labor, as they do at present, incentives are never going to lead to an abandonment of fruit farming, even when profits are strongly negative. As a consequence, the system retains most of the labour it employs even in the worst scenarios (world markets).

Water usage is already highly efficient, as it is based mainly on drip irrigation, and all scenarios are characterized by a slight further reduction in water use. The amount of water used does not change significantly, however, at least in the case of those farms with a crop mix based only, or mainly, on fruit. Clusters with a relevant percentage of annual crops display greater changes, usually characterised by a shift from irrigated to rain-fed annual crops. Once this adaptation has taken place, nevertheless, the water demand curve becomes rather rigid.

Other indicators show contrasting results in different scenarios, but no change is particularly significant. Environmental impact is strong, and remains relatively stable across scenarios.

On thewhole, alternative scenarios and different possible approaches to water policy are likely to have minor effects on the fruit system. This result is common to most fruit farming in Emilia-Romagna, but is not true of all irrigated fruit systems, which are relatively common in other parts of the country as well. In particular, in many areas fruit farming is more strongly based on irrigation (e.g. the kiwi system in the hills of Romagna, the apricot systems in the South) and/or does not benefit from the favourable environmental conditions in this area. In such cases, the impact on profitability would have a much stronger effect on the sustainability of fruit farming.

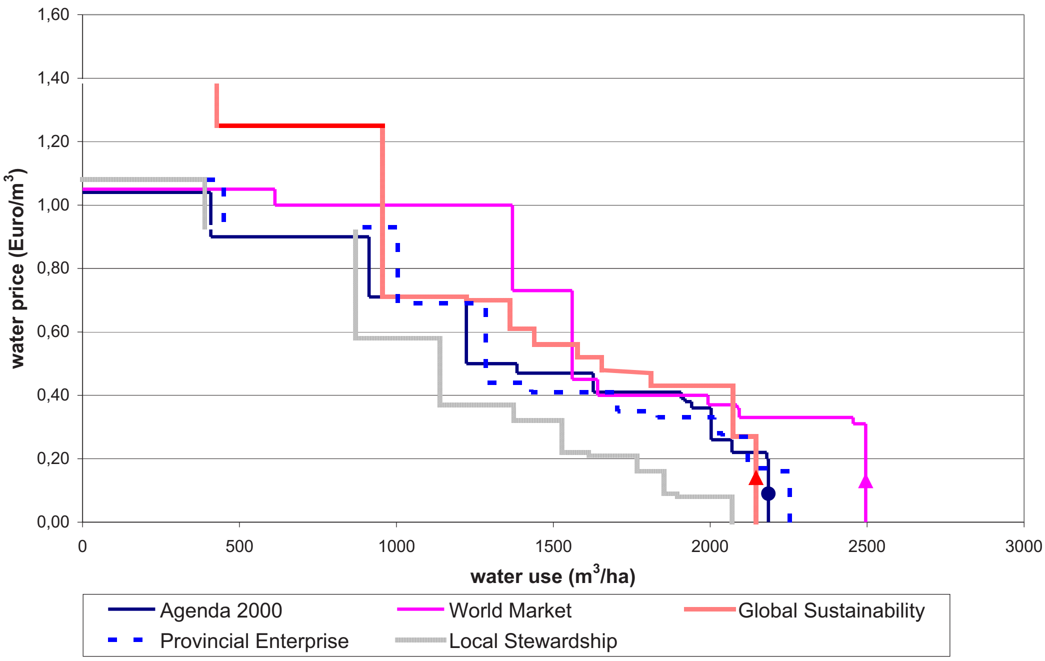
Environmental improvements would be desirable in the area, which lies within a region with relatively high pollution, (despite efforts to reduce pesticides in recent years and to introduce more natural forms of pest management and organic farming methods. Present pollution pressures are 90 kg/ha per year of nitrogen and 10 kg/ha per year of active matter of pesticides (21 kg/ha per year of total products). However, the low reactivity of the system means that few benefits are to be expected whatever policy is adopted.

5.4. Vegetables - Apulia

The cultivation of vegetables (rotated with durum wheat) accounts for about 8% of available farmland in Southern Italy, although it is much more important in economic terms. Farming accounts for: 21% of employment and 9% of GDP in the province of Foggia; 12% of employment and 5% of GDP in Apulia as a whole. The area is characterised by high unemployment (24%) and a relatively low level of income, with GDP per capita standing at around 11,000 euro.

Figure 9.6 shows the demand curves for water for the vegetable system in various different scenarios.

Figure 9.6. Demand curve by scenario.



Demand varies significantly from one scenario to another, although the latter do display a common trend. With the exception of local community, all demand curves show the first step above the present water price. This means that pricing policies would produce a reaction, in terms of water use, only if there were a significant price increase (around double). As the distribution system already allows for metering, and the demand curve shows little elasticity in the lower part, the adoption of a pricing policy below this threshold would mainly serve to recover costs.

Table 9.9 shows the impact indicators by scenario, both in terms of absolute value and percentage variation.

Table 9.9. Impact indicators by scenario (absolute value and percentage variation from Agenda 2000)

		Economic Balance			Social Impact		Landscape and Biodiversity		Water use	Nutrient and Pollutants		
		Profit	**Farm contribution to GDP**	**Public support**	**Farm employment**	**Seasonality**	**Genetic diversity**	**Soil cover**	**Water use**	**Nitrogen balance**	**Pesticide risk**	**Energy balance**
	Scenario	€/ha	€/ha	€/ha	hours/ha	index	index	index	m^3/ha	Kg/ha	index	MJ/ha
vegetables	World Market	75.77	2384.37	0.00	100	0.09	3.75	0.55	2496	91	112756	-110686
		-85%	-8%	-100%	9%	1178%	7%	3%	14%	27%	18%	-7%
	Global sustainability	514.04	2881.98	300.56	92	0.03	3.10	0.53	2145	74	71084	-99353
		5%	11%	-6%	1%	261%	-12%	0%	-2%	4%	-26%	4%
	Provincial Enterprise	369.62	2597.45	316.38	92	0.03	3.10	0.53	2253	78	111536	-104534
		-24%	0%	-1%	1%	261%	-12%	0%	3%	9%	17%	-1%
	Local stewardship	-132.11	2147.12	375.92	85	0.00	3.00	0.52	1852	63	57599	-94724
		-127%	-17%	17%	-7%	-100%	-14%	-2%	-15%	-12%	-40%	9%

The economic results vary according to the scenarios, as a result of variations in the amount of public support for, and in the prices of, durum wheat, counter-balanced by the changing cost of raw materials, including water. In fact, the world market and the local community scenarios give the worst economic results. Global sustainability would allow for moderate environmental concern, but also the valorisation of high quality local products, and as such would yield the best results in terms of profit and GDP. The differences among scenarios are more evident in terms of profit, while the agricultural contribution to GDP tends to be relatively stable. Farm employment also tends to be rather stable, showing the system's ability to cope with market trends in different scenarios.

Landscape and biodiversity are also rather stable.

The lowest results for water use are those in the local community scenario (where water prices are higher), while the world market seems to encourage increased use, due to the low price of water together with a reduction in the relative profitability of rain-fed crops (durum wheat).

Similar trends can also be seen with regard to environmental issues, particularly in the case of nitrogen and pesticides. World market and provincial agriculture causes an increase in pollution, while the other scenarios show significant reductions.

On the whole, the impacts are likely to be of average importance on a regional scale. On the one hand, variations in the main indicators are not particularly strong. On the other hand, the system in question is located within an area characterized by a serious problem of unemployment, where any source of income is potentially important.

Moreover, in spite of its stability, the vegetable system relies very much on tomatoes grown for industrial use, instead of a balanced mix of crops, which in turn exposes it to the risk of excessive specialisation. Furthermore, the production of such tomatoes provides important raw materials for the food processing industry. In the face of such issues, there seems to be little likelihood of seeing any reduction in pollution, as the region is characterised by an average use of nitrogen fertilisers and the low employment of pesticides, 60 kg/ha per year and 7 kg/ha per year of active matter (13.7 of total products), respectively.

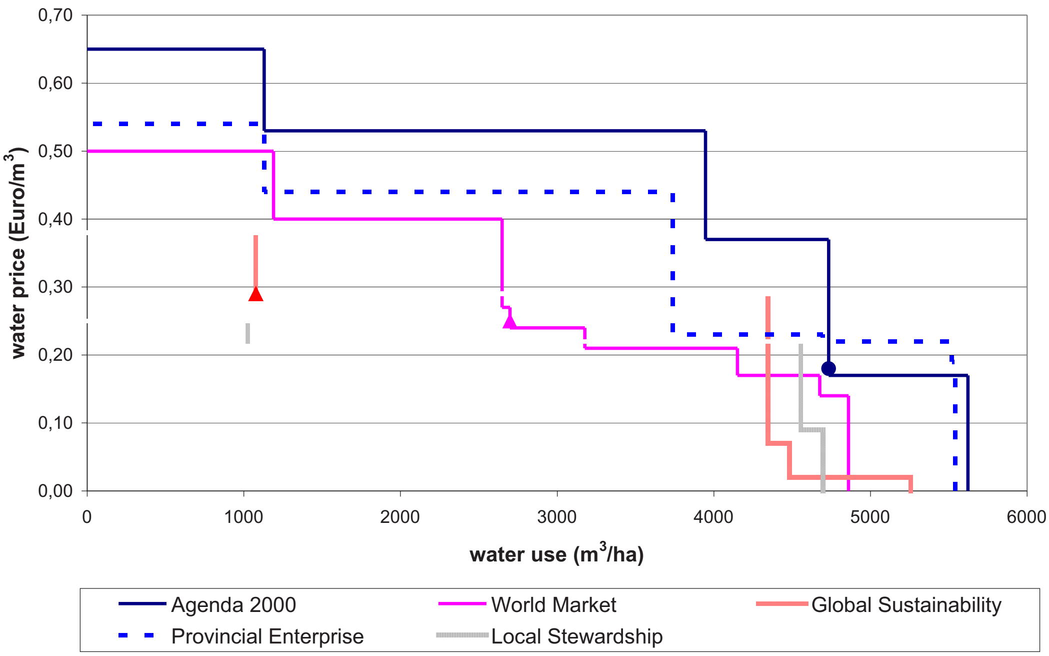
As regards water, while it is possible to use water pricing as a way of regulating its use, nevertheless this option needs to be considered against the risk of bringing down incomes in one of the few agricultural systems still capable of making a significant contribution to the local economy.

5.5. Citrus Fruit - Sicily

The citrus fruit system represents one of the main labour-intensive farming systems in mainland Southern Italy (accounting for about 2% of farmland) and on the two major Italian islands (5% of farmland, with peaks of around 30% in some provinces of Sicily). The area is characterised by low income (GDP of 14,000 euro per capita), a high level of unemployment (24%), emigration and social problems. Agriculture accounts for 11% of employment and 4.7% of GDP in the province of Syracuse; 9% of employment and 4.2% of GDP in Sicily as a whole.

Figure 9.7 shows the demand curves for water of the citrus system in the various different scenarios.

Figure 9.7. Demand curve by scenario



The demand curve reveals the existence of very important differences, particularly at high prices. In fact, while the behaviour of the curves is relatively similar for prices of up to 0.2 euro/m^3, with differences in the order of +20%, above this threshold the said behaviour varies considerably; the lowest demand is that produced in the local community scenario. Most of the scenarios assume that a price change of more than 0.2 euro/m^3 is to be expected, and so the important part of the curve is the upper one.

There are significant implications for pricing policies. While, in the baseline scenario, increasing prices only lead to marginal changes in water consumption, the regulation of demand through pricing would make much more sense in the other scenarios. It must be said, however, that the steps in the curves are rarely given by changes in the crop mix, and are only partially produced by technical change. More often they represent the abandonment of farming by less efficient (smaller) farms. In the longer run, small farms would indeed be taken over by the more efficient (larger) ones: the risk to the citrus fruit system resulting from high water pricing would be high.

The combined effects of water pricing and scenario analysis are clearer when the whole range of possible impacts is considered. Table 9.10 shows the impact indicators by scenario, both in terms of absolute value and percentage variation.

All the scenarios show the structural weakness of this agricultural system. Profits are low or negative due to the labour-intensive nature of this kind of farming. Moreover, income is limited as the produce is sold “on the tree”. Indeed, the system is never profitable, whatever the imagined scenario. The contribution to GDP, and probably net income, are only positive in the provincial agriculture and world market scenarios. The system may only be expected to continue producing citrus fruit, with no relevant changes compared with the present situation, in such cases, even if profits are strongly negative and water consumption very high. When citrus cultivation is no longer, oranges may be replaced by a rain-fed crop mix based on durum wheat. Profit itself may even improve in some scenarios, but there will be considerable social consequences as the employment of labour plummets to almost zero.

Table 9.10. Impact indicators by scenario (absolute value and percentage variation from Agenda 2000).

		Economic Balance			Social Impact		Landscape and Biodiversity		Water use	Nutrient and Pollutants		
		Profit	**Farm contribution to GDP**	**Public support**	**Farm employment**	**Seasonality**	**Genetic diversity**	**Soil cover**	**Water use**	**Nitrogen balance**	**Pesticide risk**	**Energy balance**
	Scenario	€/ha	€/ha	€/ha	hours/ha	index	index	index	m^3/ha	Kg/ha	index	MJ/ha
citrus	World Market	-859.44	618.70	0.00	78	0.00	1.64	0.67	1190	60	43062	-18933
		52%	-82%	-	-85%	-100%	64%	-33%	-75%	-65%	-12%	21%
	Global sustainability	-496.58	-116.68	208.05	1	0.00	1.00	0.55	0	9	14533	-15801
		72%	-103%	-	-100%	-100%	0%	-45%	-100%	-95%	-70%	34%
	Provincial Enterprise	-2814.20	2170.31	47.51	449	0.00	1.47	0.90	3739	137	40379	-23014
		-56%	-36%	-	-16%	-100%	47%	-10%	-21%	-21%	-17%	4%
	Local stewardship	-525.27	-144.12	219.00	1	0.00	1.00	0.55	0	8	13495	-14970
		71%	-104%	-	-100%	-100%	0%	-45%	-100%	-95%	-72%	37%

The abandonment of citrus fruit farming would produce positive environmental effects (a reduction in nitrogen pollution and no further need for irrigation), but it would lead to major social problems and the marked alteration of the local landscape.

Altogether, all scenarios would have strong negative effects on the area. The worse scenarios, such as the world market, would lead to a reduction of more than 50% in employment in farming in the local area.

The problem of the fall in employment would affect not only the farms themselves, but also workers hired by farmers to harvest the oranges, and the associated activities along the food chain. Compared with such social issues, the possible environmental benefits appear of little relevance. Sicily has a low level of nitrogen fertilizer use (40 kg/ha per year), while the use of pesticides is average (11.2 kg/ha per year of total products, about 7 kg/ha per year of active matter).

The analysis is more complex when it comes to water, as there is strong competition between domestic, industrial and agricultural users during the summer. The scenarios assume that domestic and industrial uses prevail.

However, the social importance of citrus farming could also lead to a more balanced pricing strategy. The possibility that citrus farming be gradually abandoned in the area is very hard to accept, even in the long term, due to transaction and reorganisation costs. The worst scenarios would probably lead to the gradual abandonment of farming, to be replaced in the long term by the more extensive cultivation of annual crops. It is likely that such a hypothesis would encourage the forces-that-be to act on local policies for the conservation of the local environment and traditional farming, possibly coupled with greater efforts at improving water saving systems, for example through the construction and/or use of better irrigation systems.

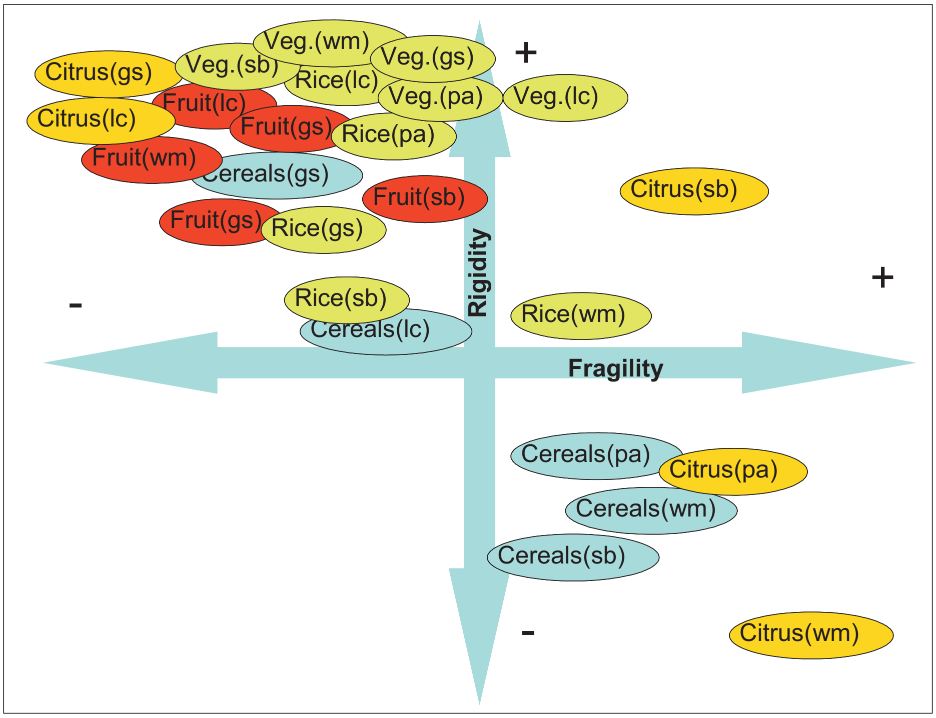
6. CONCLUSIONS AND RECOMMENDATIONS

The analysis carried out yields two main kinds of result:

- a diagnosis of the sustainability of the various farming systems when faced with various different scenarios;
- the associated policy implications for CAP and WFD.

A summary of the sustainability of different farming systems is sketched in figure 9.8.

Figure 9.8. A classification of Italian irrigated systems



Rigidity refers to the inelasticity of the demand curve for water in the proximity of the present price of water. Fragility refers to the sensitivity of income (GDP) to changes in the price of water. The overall sustainability of the system is determined both by the reaction to changes in water policy and by the reaction to changes in agricultural policy and in the overall context.

Some systems are both relatively stable in terms of income, and characterized by a generally rigid demand curve (e.g. the fruit system). In this case, while pricing could be a useful means by which to satisfy environmental and budgetary requirements (the "Polluter pays principle" – PPP; "Full costs recovery" - FCR), it is unlikely that it would be a suitable instrument for providing incentives to farmers to reduce water use or contain pollution. FCR may be used, and farms will probably be able to bear the cost, but pricing policy will not be particularly effective in reducing water use. Moreover, due to the system's rigidity, it will display little response to water pricing in terms of economic, social and environmental sustainability.

Pricing policies are also likely to show low cost-effectiveness. On the other hand, the existing distribution system allows for the simple application of pricing concepts.

Other systems, such as citrus fruit farming, are relatively rigid but also fragile. In this case, flexibility is associated with the considerable impact on the production of income and on the economic and social sustainability of the system. Increasing water price will not be effective right up to the threshold where citrus farming is abandoned altogether. The price of implementing water policy principles such as FCR and PPP will be to jeopardize the whole system, including its economic, social and environmental features.

Vegetables are very rigid due to the high profitability of irrigation. The low reaction to water price is simply associated with the maintenance of vegetable farming. This means that FCR, PPP and pricing could be applied to the system, and would give reasonable results, without putting the livelihood of the system at stake.

On the contrary, more flexible, yet more fragile, annual crop systems (rice systems and, even more so, cereal systems) would react more strongly to water pricing, and this would lead to the expected reduction in water use. Water policy may be cost-effective, and is likely to bring about significant changes in the environmental performance of the farm. On the other hand, applying PPP or FCR to water pricing in this area could easily lead to excessive water prices, which could compromise the economic sustainability of the farming system.

Three issues need to be considered if we are to fully understand the practical implications of policy here.

First of all, in many areas the water distribution network is based on open canals. In such cases, the “first best” solution requiring metering may be not socially profitable, due to the cost of metering, monitoring and the related transactions. Flat-rate payments could be differentiated among crops instead, in order to encourage or discourage irrigation, according to the environmental and water-saving characteristic of the agricultural techniques adopted.

Secondly, in many areas the assumption that reducing water consumption is always an environmental objective may be somewhat oversimplified, or even simply not true (as in the study area where rice is grown). This calls for a more cautious calculation of the costs and benefits, both direct and indirect, of water use, in order to provide for an economic analysis more in keeping with social expectations and the political perception of the relevant issues.

Thirdly, the various scenarios show that in some cases, there may be significant changes in water use as the result of changing agricultural prices. In scenarios characterised by a strong degree of liberalisation (or by decoupled payments) a reduction in water consumption may suffice, without the need for strict pricing policies.

In fact, CAP and water policy objectives sometimes appear contradictory (as in the case of irrigated cereals), while they may appear synergic in other cases (such as that of rain-fed cereals combined with irrigated vegetables or fruit). In the former case, CAP payments are associated with irrigated crops, and thus encourage higher water consumption. In the latter case, CAP payments are associated with rain-fed crops, and thus their increase may encourage a shift from irrigated to non-irrigated crops. There may be a need for a common policy design framework (or at least greater attention to policy co-ordination at the local level), if undesired economic, social and environmental effects are to be avoided. In such process, the availability of a sufficiently wide set of sustainability indicators may aid policy making.

The present study highlights the need for further research into:

- water policy design, taking into account various different policy instruments, information structures and transaction costs; innovative forms of water management could be analysed, such as water markets, tradable permits, mixed instruments; other aspects of water policy, such as water recycling, the use of waste water and quantitative regulation aimed at dealing with drought periods, should also be considered;

- the comprehensive modelling of economic(-environmental) interaction at basin level, that could generate informative synergies with the farm-level analysis developed in WADI;
- the introduction of issues such as the relationship with agricultural-environmental schemes;
- the introduction of more detailed economic analysis in the development of decision support systems;
- the integrated analysis of other water uses;
- issues such as seasonality, water storage, conservation and transport.

The work carried out during WADI has allowed for the development of a methodology of data collection, simulation and output representation that can be usefully applied to further analysis and future projects. In particular, the methodology adopted (and the analysis carried out) could be successfully employed in relation to the economic studies designed to support WFD implementation. It could also be adapted to provide micro-analysis to support the upper-level modelling of the behaviour of farming systems in relation to water policy. These further activities should be carried out in conjunction with a wide range of local actors - such as river basin authorities, farmers' associations and irrigation boards - in order to aid the drafting of river basin plans and monitoring programs in the most participative and transparent way possible. The methodology's potential could be better exploited if there were an improvement in data sources (e.g. FADN) capable of proving a larger amount of technical and economic data on which to build the models.

Finally, the methodology does not focus exclusively on water issues. On the contrary, it could be used for a much wider range of policy analysis issues pertaining to agriculture (e.g. MTR), particularly when the simulation of farm-level adaptations is required.

10.

The Case of England and Wales

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1. Background

1.1. Purpose and contents

This report summarises the findings of an EU funded study (WADI) to assess the impact of policy change on the sustainability of irrigation sector in England and Wales. The study identified the main types and characteristics of irrigation farming systems. Particular attention was paid to the value of water for irrigation, and the economic, social and environmental performance of irrigation in absolute terms and relative to rainfed alternatives. The possible impacts of changes associated with reform of the Common Agricultural Policy and the new Water Framework Directive were explored using a scenario based approach. The results of the analysis at farm level were interpreted for the regional and national irrigation sector. (The exchange rate used for the period of study was £1 = 1.5€)

1.2. Characteristics of irrigation in England and Wales

Most UK irrigation occurs in specific regions of England, with small amounts in Wales and Scotland and relatively little in Northern Ireland. The study focuses on England and Wales (E&W), although some data refers to the UK as a whole. Table 10.1 shows the areas of irrigated crops and the volume of water applied for E&W.

Table 10.1 Areas of irrigated crops and volume of water applied, E&W, 2001

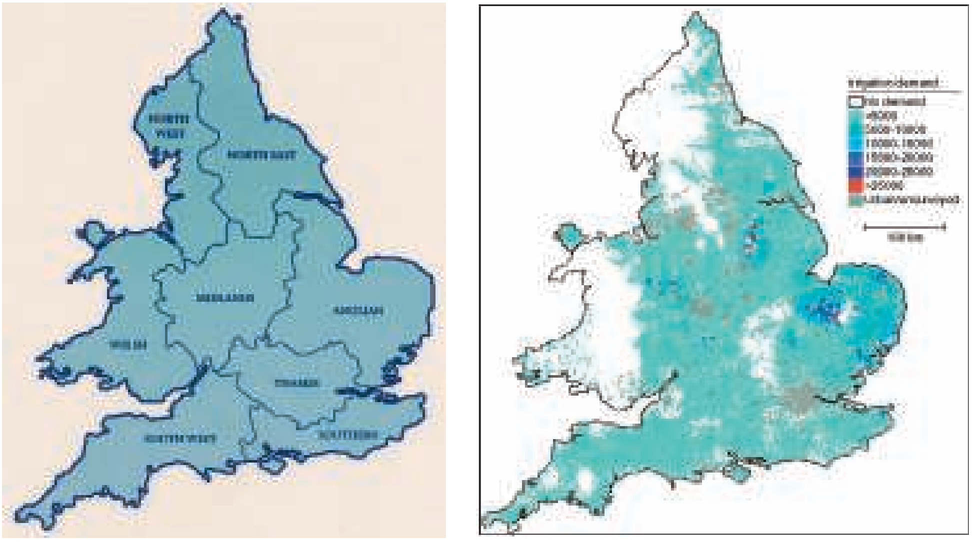
	Area		**Water Volume**		**Irrigation as % of Total Crop Areas**
	ha	**%**	**1000 m^3**	**%**	**%**
Early Potatoes	7,628	5	5,872	4	43
Maincrop Potatoes	70,006	47	70,057	53	47
Sugar beet	9,755	7	4,633	3	13
Orchard fruit	1,578	1	896	1	10
Small fruit	3,774	3	3,312	2	32
Vegetables	39,164	26	34,114	26	23
Grass	4,104	3	2,470	2	0.2
Cereals	4,615	3	1,471	1	0.5
Other crops	7,272	5	8,841	7	11
Total of Outdoor crops	147,895	100	131,755	100	1.5

Source: Weatherhead and Danert, 2002

Irrigation is a commercial activity carried out by farmers mainly on an individual basis, with licensed abstractions from surface and groundwater. There are virtually no public investments for irrigation water supply, although in some areas farmers benefit from control of river water levels carried out by regulatory authorities. The irrigation sector in E &W has the following characteristics.

- Irrigation is supplementary to rainfall, and for this reason the area that is irrigated tends to vary from year to year, covering between about 140,000 ha and 200,000 ha, equivalent to about 1.5% of the total cropped area of E&W. Since most of this is in a rotation including rainfed crops, a significantly larger proportion of the land is involved in an irrigated rotation, probably about 7 to 8% of total cropped areas.
- The major irrigated crops in England and Wales are potatoes, vegetables and sugar beet, which together accounted for about 85% of the total irrigated area in 2001. Potatoes alone account for over 54% of the irrigated area. Over 50% of all potatoes are now irrigated, mainly for the purpose of quality assurance.
- Irrigation is regionally focussed, with over 50% occurring in the drier eastern part of England (Anglian), followed by the Midlands (19%), Thames (10%) and Southern (9%) regions. Figure 10.1 shows the regional areas designated by the Environment Agency which is responsible for water resource management. Figure 10.1 also shows the distribution of water demand for irrigation (by volume) in areas which contain irrigation

Figure 10.1 Regional areas in England and Wales and areas of irrigation demand (m^3/km^2)



Source: Weatherhead *et al*, 1997

- Total irrigation water use in E & W is about 140 million m^3 per year. Although this is less than 1.5% of total abstraction, during peak periods irrigation can account for more than 70% of total abstraction in the intensively irrigated areas of Eastern England.

- The amount of water used for irrigation doubled in the period 1975 to 2000. Over this period, there has been an underlying increase in water use for irrigation in the eastern counties of about 3% per year.

- Average seasonal application depths of irrigation water are relatively small, reflecting the supplementary nature of irrigation, typically ranging from 40-60 mm for soft fruits, through to 150 to 220 mm for potatoes, depending on rainfall.

- About 58% of total abstraction for irrigation comes from surface water sources, 35% from groundwater, and about 3% from public mains, the latter mainly for specialist and amenity cropping.

- Mobile hose-reel operated rain guns and booms account for over 90% of infield applications systems (figure 1.3). About 3% of the area uses trickle and drip systems; this has grown considerably in recent years.

- In response to seasonal shortages of water, and restrictions on summer abstraction licences, the amount of water stored in on-farm reservoirs doubled from 33 million to 64 million m^3 in the period 1984 to 1995 (Weatherhead et al., 1997, MAFF, 2000)

Figure 10.2. Illustrations of Irrigation Systems


Boom on Lettuce


Rain gun on Salad Onions


Centre Pivot on Potatoes


Trickle Tape on Potatoes


Trickle on Potatoes


Irrigation Storage Reservoir

The main drivers for irrigation in England and Wales are the price incentives provided by commodity markets for farm produce. With the exception of sugar beet, most irrigated crops in the UK do not receive direct Government support. As a consequence, irrigated crops tend to be less policy dependent and more market oriented than non-irrigated crops such as cereals, protein crops and oils seeds which receive support under the Common Agricultural Policy (CAP).

In E&W supplementary irrigation is mainly undertaken to assure the quality of crops demanded by increasingly sophisticated markets, especially for fresh produce. Irrigation enables growers to meet commodity specifications with respect to size, shape, appearance, bio-physical characteristics such as sugar content and skin condition, and delivery time to market. It is less concerned with yield enhancement.

2. DERIVATION AND DESCRIPTION OF IRRIGATION CASE STUDIES

Results from 2301 holdings (41% of the eligible population) in the 2001 Survey of Irrigation of Outdoor Crops in England and Wales (Weatherhead and Danert, 2002) were used to determine the main types of irrigation farming, classified by key characteristics, notably cropping pattern, size of irrigated areas, region, water sources and application systems. These data were supported by visits to 24 irrigation farms, targeted questionnaires for selected specialist growers, interviews with key informants and a review of farm business survey data.

It was found that 30% of all holdings that practised irrigation in 2001 accounted for over 80% of the irrigated area and irrigation water use. A cluster analysis was carried out for this group of holdings (table 10.1). Potatoes dominate the classification, but there is sufficient variation in the way that potatoes are combined with other crops to warrant classification according to combinations of potatoes and other crops.

Table 10.2. Dominant irrigated farming systems within the top three deciles of holdings with irrigation, 2001, E&W

Crops % of Irrigated areas	Maincrop potato specialist	Pot And Sugar Beet	Veg and Pot	Pot and Veg	Pot, Veg and cereals (pivot/gan-try)	Small fruit	Other crops	Fruit and Veg
Early Potato	3%	14%	4%	4%	0%	0%	1%	1%
Maincrop Potato	88%	24%	17%	34%	32%	2%	8%	12%
Sugar Beet	2%	26%	1%	10%	7%	0%	3%	3%
Orchard Fruit	0%	2%	0%	0%	0%	3%	0%	23%
Small Fruit	0%	1%	1%	0%	14%	78%	0%	3%
Vegetables	4%	9%	77%	38%	19%	0%	0%	49%
Grass	1%	10%	0%	2%	8%	16%	0%	0%
Cereals	0%	11%	0%	4%	18%	0%	0%	0%
Other Crops	2%	3%	0%	7%	1%	1%	88%	8%
Average ha Irrigated	74	77	107	130	280	71	58	70
% of Area of Total Group	40%	19%	16%	15%	4%	2%	2%	2%
% of TOTAL National Area in each cluster	33%	16%	13%	12%	3%	2%	2%	2%
% of Farms of Total group	46%	21%	13%	10%	1%	2%	3%	3%
% of ALL Irrigated Farms Nationwide	14%	6%	4%	3%	0%	1%	1%	1%

Irrigation Farming Systems, E & W, 2001

Additional data were derived from the Department for Environment, Food and Rural Affairs (Defra) 2001 Agricultural Census for England and Wales in order to match irrigation characteristics with whole farm characteristics such as farm size, rainfed cropping, and size of labour force. This enables the irrigation activity to be placed in a whole farm context. Table 10.2 shows the main characteristics of the clusters used for the purpose of modelling.

The irrigation farming systems used for analysis are regarded as indicative types. There is considerable variation within the clusters with respect to the detail of crop mix, the percentage of the area irrigated, the proportion of the farm that is under irrigation command, and sources of water. The clusters tend to show greater diversity of cropping than that found in practice on any one farm. Nevertheless, they were considered a valid basis for analysis. Alternative classifications were considered, especially regarding farm size and percentage of the farm irrigated, but the results regarding water values and performance were similar.

Table 10.3. Whole farm characteristics of irrigation farm clusters based on 2001 Census Data

	Specialist potato	Potato and vegetable	Potato and sugar beet	Vegetable and horticulture	Soft fruit
No. of farms (n=431)	129	82	47	47	129
Size (ha)	479	476	352	260	65
% of land irrigated	18	34	27	57	14
Potatoes (%)	14	9	9	4	0
Cereals (%)	49	44	50	38	31
Vegetables (%)	7	15	6	33	6
Sugar beet (%)	10	10	13	0	3
Fruit (%)	0	0	0	0	33
Oil seed rape (%)	5	5	4	7	5
Set aside (%)	5	8	8	12	9
Other (%)	10	8	10	8	12

3. RESULTS

The results of the analysis of the performance of irrigation systems for the Existing (Agenda 2000 Reform) scenario are presented here in summary form. The analysis considers the impact of incremental restrictions in water supply for irrigation in order to determine relative performance compared to the rainfed option and the value of irrigation water at the margin of use. The implications of using regulatory and economic instrument to achieve water resource management objectives are considered.

3.1. Irrigation costs

A review of irrigation costs showed that average total irrigation costs for relatively large irrigated areas (50 ha and over) are about £0.33/m^3 (0.43€/m^3) applied in the field, rising to about £0.45/m^3 (0.7€/m^3) with clay lined storage reservoirs, and over £0.60/m^3 (0.9€/m^3) with artificially lined reservoirs. Water costs are less than 7% of total costs. Thus, at current abstraction charges, summer direct abstraction is always cheaper per m^3 than winter stored water. Summer charges would need to rise to about £0.15p/m^3 (0.27€/m^3) or so for winter stored water to be a cheaper option. But additional summer water is not available in many situations. The average total costs using trickle systems range between £0.55 and £0.75/m^3 (0.8€ and 1.35€/m^3) (Knox and Weatherhead, 2003).

3.2. Observed and modelled results for irrigation farming systems

Table 10.4 shows the observed and modelled whole farm cropping patterns for the selected irrigation farming systems. The differences are minor, mainly reflecting the fact that the observed farm types are based on an 'average' which rarely exist in practice.

Table 10.4. Observed and modelled results of irrigated farming systems, E&W

	Specialist potato		Potato and Vegetables		Potato and Sugar Beet		Vegetable and Horticulture		Fruit	
	O	M	O	M	O	M	O	M	O	M
No. of farms (n=431)	129		82		47		47		47	
Size (ha)	479	500	476	500*	352	350	260	260	65	65[+]
% of land irrigated	18	17	34[$]	25	27	25	57[$]	40	21	30
Potatoes (%)	14	17	9	8	9	10	4	0	0	0
Cereals (%)	49	50	44	46	50	54	38	33	31	50
Vegetables (%)	7	<1	15	17[a]	6	1[a]	33	40[a]	6	0
Sugar beet (%)	10	6	10	12	13	14	0	0	3	0
Fruit (%)	0	0	0	0	0	0	0	0	33	30
Oil seed rape (%)	5	10	5	0	4	7	7	8	5	14
Set aside (%)	5	7	8	6	8	7	12	5	9	6
Other (%)	10	10	8	12	10	7	8	9	12	0

O= observed based on clusters from survey data. M=modelled
alternative sizes were also modelled 300 ha with 50% of area irrigated, +25ha with 100% area irrigated
$ difference between O and M % of land irrigated are attributable to declarations of occasional and limited irrigation of cereal or other unspecified crops which are not critical to the definition of the cluster.

3.3. Irrigation farming systems: Impact of water restrictions

3.3.1.- *Specialist irrigated potato farms*

Table 10.5 shows the cropping pattern for the specialist potato grower under varying amounts of water supply. Incremental reductions in water available impose a switch to rainfed cropping, resulting in successive reductions in the area of potatoes. It is assumed that in these areas of irrigation need, potatoes cannot be grown reliably to the quality standard required by the market in the absence of irrigation.

Table 10.5. Cropping patterns (% of farm area) for specialist irrigated potato farming system for given available irrigation water supply (% of unrestricted water requirements):

Water availability	100%	75%	50%	25%	0%
Rainfed					
Winter Wheat (first crop)	50%	50%	50%	50%	50%
Field Beans	7%	7%	9%	10%	10%
Sugar beet	12%	12%	12%	12%	12%
Onion	0%	0%	0%	5%	11%
Oilseed rape	7%	7%	9%	10%	10%
Set aside	6%	6%	7%	7%	7%
Rainfed land	83%	83%	87%	94%	100%
Irrigated					
Potatoes	17%	17%	13%	6%	0%
Irrigated land	17%	17%	13%	6%	0%
Total Land (500 ha)	100%	100%	100%	100%	100%

Under rainfed farming, cropping reverts to a mainly wheat, beet and beans/oil seed rape rotation. The rainfed system includes some vegetable crops such as onions to take the place of irrigated potatoes, but much would depend on local conditions, including access to market.

3.3.2.- *Potato and vegetable farms*

In the unrestricted water supply situation, equal areas of potatoes, onions and carrots are irrigated (table 10.6). Incremental reductions in water available impose a switch to rainfed cropping, resulting in successive reductions in the areas of onions, carrots and potatoes in accordance with their relative returns to water. These crops could not be grown reliably to the quality standard required by their markets in the absence of irrigation. In the absence of irrigation, cropping reverts to a mainly wheat, beet and beans/oil seed rape rotation.

Table 10.6. Cropping patterns (% of farm area) for potatoes and field vegetable irrigated farming system for given available irrigation water supply (% of unrestricted water requirements)

Water availability	**100%**	**75%**	**50%**	**25%**	**0%**
Rainfed					
Winter Wheat (first crop)	38%	38%	38%	38%	38%
Winter Wheat (second crop)	8%	8%	8%	15%	20%
Spring Wheat	0%	0%	0%	0%	2%
Field Beans	6%	6%	10%	10%	10%
Oilseed rape	6%	6%	10%	10%	10%
Sugar beet	12%	12%	12%	12%	12%
Set aside	6%	6%	7%	7%	8%
Irrigated					
Potatoes	8%	8%	8%	8%	0%
Onions	8%	8%	0%	0%	0%
Carrots	8%	8%	7%	0%	0%
Rainfed land	75%	75%	84%	92%	100%
Irrigated land	25%	25%	16%	8%	0%
Total land (500 ha)	100%	100%	100%	100%	100%

3.3.3.- *Potato and sugar beet farms*

Where water supply is unrestricted, irrigated cropping includes potatoes and sugar beet (table 10.7). Rainfed crops are winter wheat, spring wheat (following sugar beet and late harvested potatoes), sugar beet, beans and oil seed rape.

Table 10.7. Cropping patterns (% of farm area) for potatoes and sugar beet irrigated farming system for given available irrigation water supply (% of unrestricted water requirements):

Water availability	**100%**	**75%**	**50%**	**25%**	**0%**
Rainfed					
Winter Wheat (first crop)	25%	25%	25%	25%	25%
Spring Wheat	21%	21%	21%	23%	28%
Field Beans	7%	7%	7%	7%	8%
Oilseed rape	7%	7%	7%	7%	8%
Sugar beet	10%	10%	16%	25%	25%
Set aside	6%	6%	6%	6%	7%
Rainfed land	75%	75%	81%	92%	100%
Irrigated					
Potatoes	10%	10%	10%	8%	0%
Sugar beet	15%	15%	9%	0%	0%
Irrigated land	25%	25%	19%	8%	0%
Total Land (350 ha)	100%	100%	100%	100%	100%

Incremental reductions in water available impose a switch to rainfed cropping, resulting in successive reductions in the areas of irrigated sugar beet and potatoes in accordance with their relative returns to water. The irrigated areas are substituted by rainfed sugar beet and a cereal based crop rotation.

3.3.4.- *Large scale vegetable and horticultural farms*

Although cluster analysis generated an average farm with a mix of vegetable cropping, individual cases showed a considerable degree of specialisation in one or two particular crops. The farm case used here must be regarded as indicative of the very great range of practices which are found within this type. Table 10.8 shows that reductions in water availability results in a gradual switch to a cereal based rainfed system. Rainfed vegetable cropping would be unreliable and relatively unattractive in areas of irrigation need.

Table 10.8. Cropping patterns (% of farm area) for large scale vegetable and horticultural farms for given available irrigation water supply (% of unrestricted water requirements):

Water availability	100%	75%	50%	25%	0%
Rainfed					
Winter Wheat (first crop)	50%	50%	50%	50%	43%
Winter Wheat (second crop)	0%	0%	0%	0%	0%
Spring Wheat	5%	5%	18%	19%	38%
Field Beans	0%	0%	0%	5%	5%
Oilseed rape	0%	0%	0%	5%	5%
Set aside	5%	5%	7%	8%	9%
Rainfed land	60%	60%	75%	87%	100%
Irrigated					
Winter Cabbage	8%	8%	3%	0%	0%
Celery	6%	6%	6%	3%	0%
Lettuce	16%	16%	16%	10%	0%
Calabrese	10%	10%	0%	0%	0%
Irrigated land	40%	40%	25%	13%	0%
Total Land (250 ha)	100%	100%	100%	100%	100%

3.3.5.- *Soft fruit farms*

Table 10.9. Cropping patterns (% of farm area) for soft fruit farming system for given available irrigation water supply (% of unrestricted water requirements):

Water availability	100%	75%	50%	25%	0%
Rainfed					
Winter Wheat (first crop)	50%	50%	50%	50%	50%
Spring Wheat	0%	2%	9%	14%	20%
Oilseed rape	14%	15%	17%	18%	20%
Apples	0%	1%	1%	1%	1%
Set aside	6%	7%	8%	8%	9%
Rainfed land	70%	74%	83%	92%	100%
Irrigated	0%	0%	0%	0%	0%
Strawberries	24%	24%	17%	8%	0%
Raspberries	6%	2%	0%	0%	0%
Irrigated land	30%	26%	17%	8%	0%
Total Land	100%	100%	100%	100%	100%

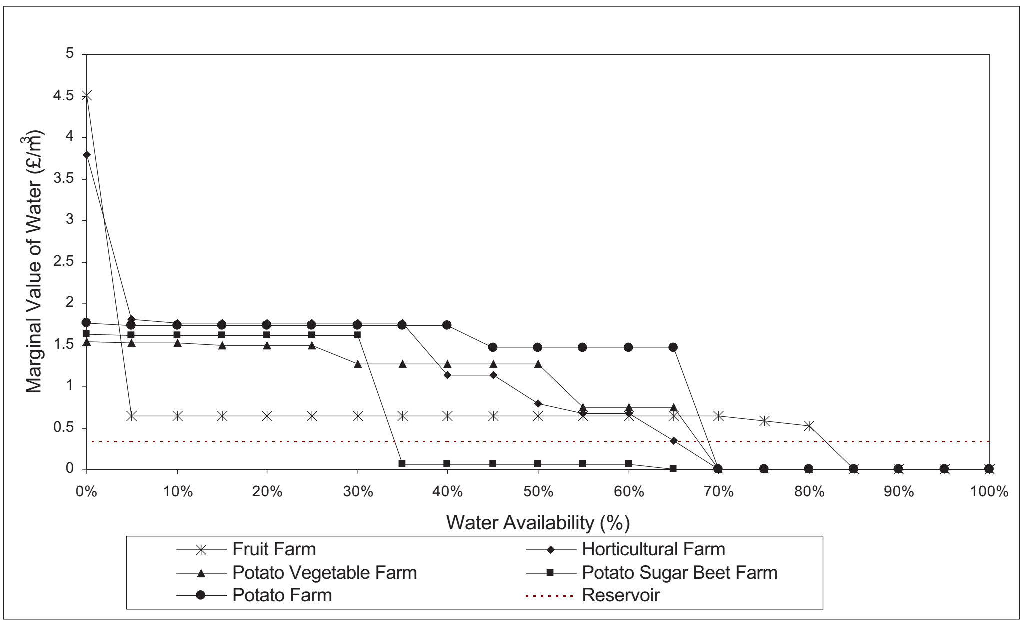
The modelled soft fruit farm has about one third of its land under soft fruit, mostly strawberries but some raspberries. Table 10.9 shows the impact on irrigation performance of incremental reductions in available irrigation water. In the absence of irrigation, the farm would switch to a cereal-based rotation. However, it would clearly not be sufficiently large to be viable as an independent cereal-based rainfed system, and would most likely be farmed using contractors, or be sold off.

3.4. Marginal value of irrigation water by farming system

Figure 10.3 contains a comparison of the marginal value of water (£/m^3) in different irrigated farming systems in England and Wales over the relevant range of water use in the average weather year (10th driest year in 20). (In the average year, farmers are typically applying about 70% of the irrigation water needed in a dry year). These 'standard' estimates also assume water abstracted in the summer, full fixed costs and hosereel systems. The marginal value of water shows the contribution to profitability (net margins/ha) of a unit of water at a given level of use, over and above the costs of the irrigation system itself. It is therefore a 'shadow' or hidden price for water.

The marginal value of water varies amongst the farming systems, according to crop response to irrigation (in terms of the value of increased yield and quality), crop mix, and the underlying profitability of crops as determined by financial net margins. Net margins are especially sensitive to the fixed costs of labour and machinery at farm level, and also to marketing costs in the case of specialist horticultural and fruit crops.

Figure 10.3. Comparison of marginal value by irrigation farming system



Note: Water availability expressed as a % of that required in 5th driest year in 20

The clear message is that irrigation water in UK gives greatest returns in market-oriented potato and vegetable farming where the emphasis is on quality assurance. Such irrigated farming systems involve over 80% of the irrigated area and water use. It is here that average water values over the relevant range of application are around £1.5/m^3 (2.25 €/m^3). Linked to this, demand is price inelastic for these crops, suggesting, at least in theory, a strong willingness by farmers to pay for secure access to water for irrigation.

By comparison, the value of water applied to sugar beet is relatively low, as shown by the estimate of marginal water value at for the potato and sugar beet farm. This ranges from £0.03/m^3 (the price paid for summer water) when not limiting, to between £0.8 and £1.90/m^3 when water is first used. However, the marginal value of water on sugar beet, a relatively low response crop, is about £0.05/m^3. Increases in water prices beyond this render the irrigation of sugar beet infeasible. Price elasticity of demand for water is high at the margin of use (on sugar beet) for this type of farm: an increase in water prices would tend to more than proportionately reduce demand.

The analysis here uses the rainfed cropping as the counterfactual comparator. In most cases, in areas of irrigation need, water resource constraints tend to exclude other high value crops since these also require irrigation to achieve reliable yield, quality and hence financial returns. This increases the apparent benefit of irrigation compared to an analysis which assumes that the counterfactual is the production of the same crops in areas of adequate rainfall. The choice of comparator depends on the scale of the analysis, whether at catchment or national level. Farmers will take a local catchment view, but the water resource agency may take a national view. Some uses of water, such as the irrigation of sugar beet or cereals do not appear valid when compared with rainfed yields at a national level, even though they may prove financially viable to some farmers at a local level.

3.5. Sensitivity analysis of water value by irrigation farming system

Figure 10.4 contains estimates for each of the modelled farming systems of the marginal value product of water at given levels of water use for different assumptions, separately assuming winter abstraction with reservoir storage, the use of trickle/drip applications, short term costs involving variable costs only and no charge for regular labour, and the dry year (5th driest year in 20).

The analysis confirms that financial returns to irrigation are higher in the short term than the long term. This might justify irrigation of low value crops if there is surplus irrigation capacity in any one year. The effect of a dry year is shown: the curves shift to the right to the point where 100% of available water is used. The area under the curve increases, denoting increased total financial returns to irrigation water. Given increased application depths, the value of water appears lower for the dry year than for the average year, but this is likely be compensated by higher commodity prices that occur during such a year.

In the face of long term restrictions on abstraction, farmers may choose to switch to winter abstraction and to invest in storage reservoirs. The latter, occurring additional costs of £0.15/m^3 to £0.30/m^3 (0.22 €/m^3 to 0.45 €/m^3), appears worthwhile except for sugar beet. A switch to trickle serves to reduce overall water demand, other things remaining constant, by increasing efficiency in use and increasing returns per unit of water applied.

3.6. Sustainability of irrigation performance

Figure 10.5 contains summaries of the performance of the irrigation farming systems in terms of selected economic, social and environmental indicators. There is a general consistency in the results across all the farming systems. In economic terms, net margins per ha fall significantly (for example by between 50% and over 70%, highest in the case of horticultural and fruit farmers) as a result of a switch to a rainfed regime. Conversely, the level of government support increases as farmers switch to subsidised cropping.

In social terms, irrigation is much more labour intensive than cereal-based rainfed cropping systems. Labour employment per ha typically falls by over 40% if irrigation is curtailed. If however the same types of crops are produced more extensively elsewhere under rainfed conditions, there may not be an overall loss in employment. Irrigated farming also tends to provide greater continuity of employment through the year.

In environmental terms, irrigated cropping is associated with greater crop diversity and increased soil cover through the year (not shown). Irrigation systems tend to demonstrate relatively high potential for diffuse pollution, unless measures are taken to guard against this. Generally, the risk of nitrate and pesticide leaching is greater under irrigated cropping compared to a cereal-based rainfed alternative, but not necessarily against rainfed cropping of similar crops. Irrigation tends to be relatively energy intensive, but for the most part generates a higher energy balance than rainfed cropping on the case study farms.

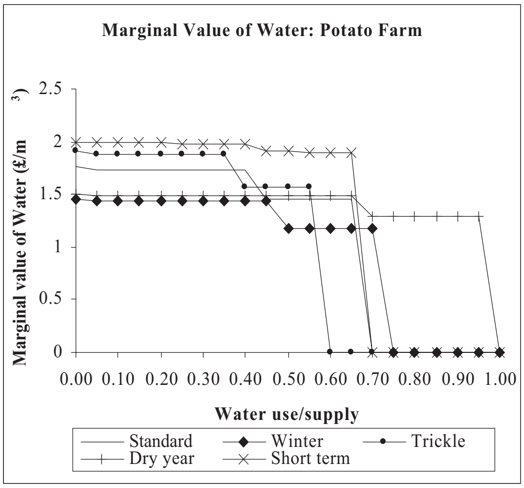
The use of selected environmental indicators here adopts a generalised and partial approach, using typical estimates of agro-chemical applications and soil and climatic conditions. Environmental indicators for water quality are only meaningful if related to the risk of ecotoxicity, which very much depends on local conditions and the sensitivity of the environmental receptor. To be useful, estimates of environmental impacts should be location specific.

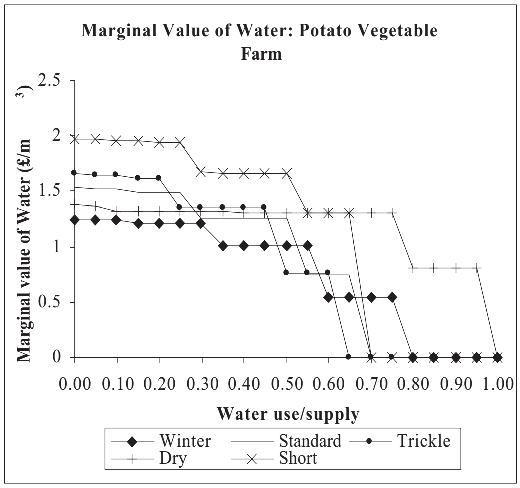
3.7. Impact of water pricing and regulation

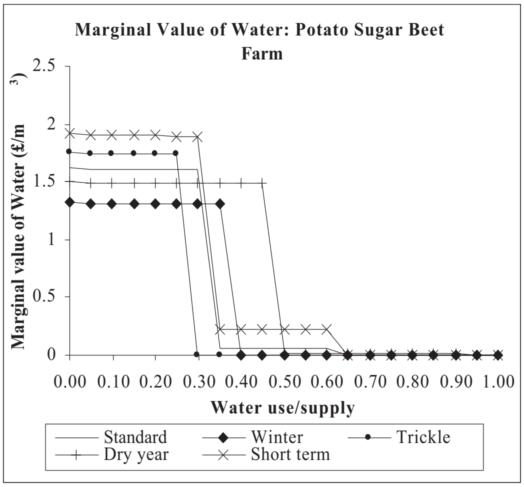
The relationships between the marginal value product of water and water supply indicate the price elasticities of demand for water for each of the farming systems and their constituent crops. The elasticities have important implications for the choice of policy instrument for a water resource management agency wishing to ration water use and/or increase efficiency in use. This is best illustrated using examples from the above cases.

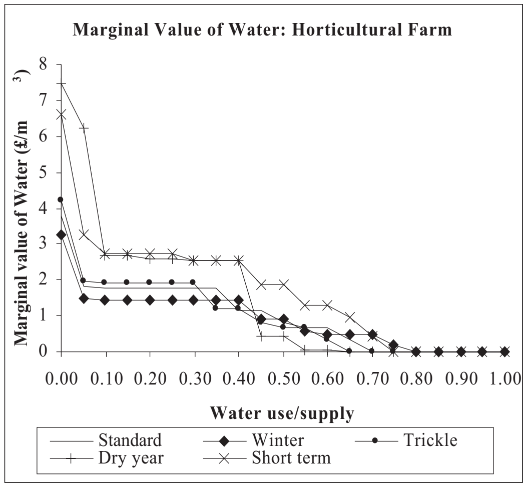
Figure 10.6 shows the case for the potato and vegetable system. A 10% reduction in water use imposed through a reduction in licensed quantities would result in a 5% fall in net margin to farmers. Given the strength of demand for water amongst this group, however, achieving a 10% reduction in water consumption using the water price mechanism would require water prices to rise from current levels of about £0.03/m^3 for summer water to about £0.75/m^3. This results in a 40% reduction in income to farmers. Farmers would, at least in the short term, be inclined to absorb the price increases before they significantly change their water consumption. In due course they would adopt strategies to avoid the high cost of summer water such as investing in winter storage. Such interventions would have a more than proportionate impact in dry years when demand is particularly strong and the income affect of regulation is that much greater (Morris et al, 1997).

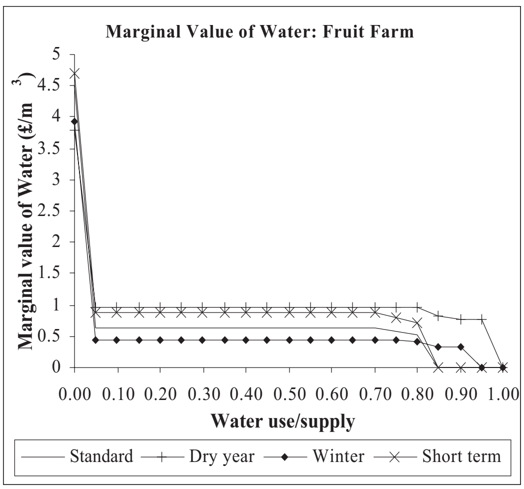
Figure 10.4. Marginal value of water by type of irrigation farming for various assumptions











Note: Standard: average rainfall year, summer water, full fixed costs, hosereel systems. Others as for Standard except: Winter: winter abstraction and storage. Trickle: trickle/drip applications. Dry year: 5th driest year in 20. Short term: variable costs only and zero charge for regular labour

Figure 10.5. Selected performance indicators for irrigation systems

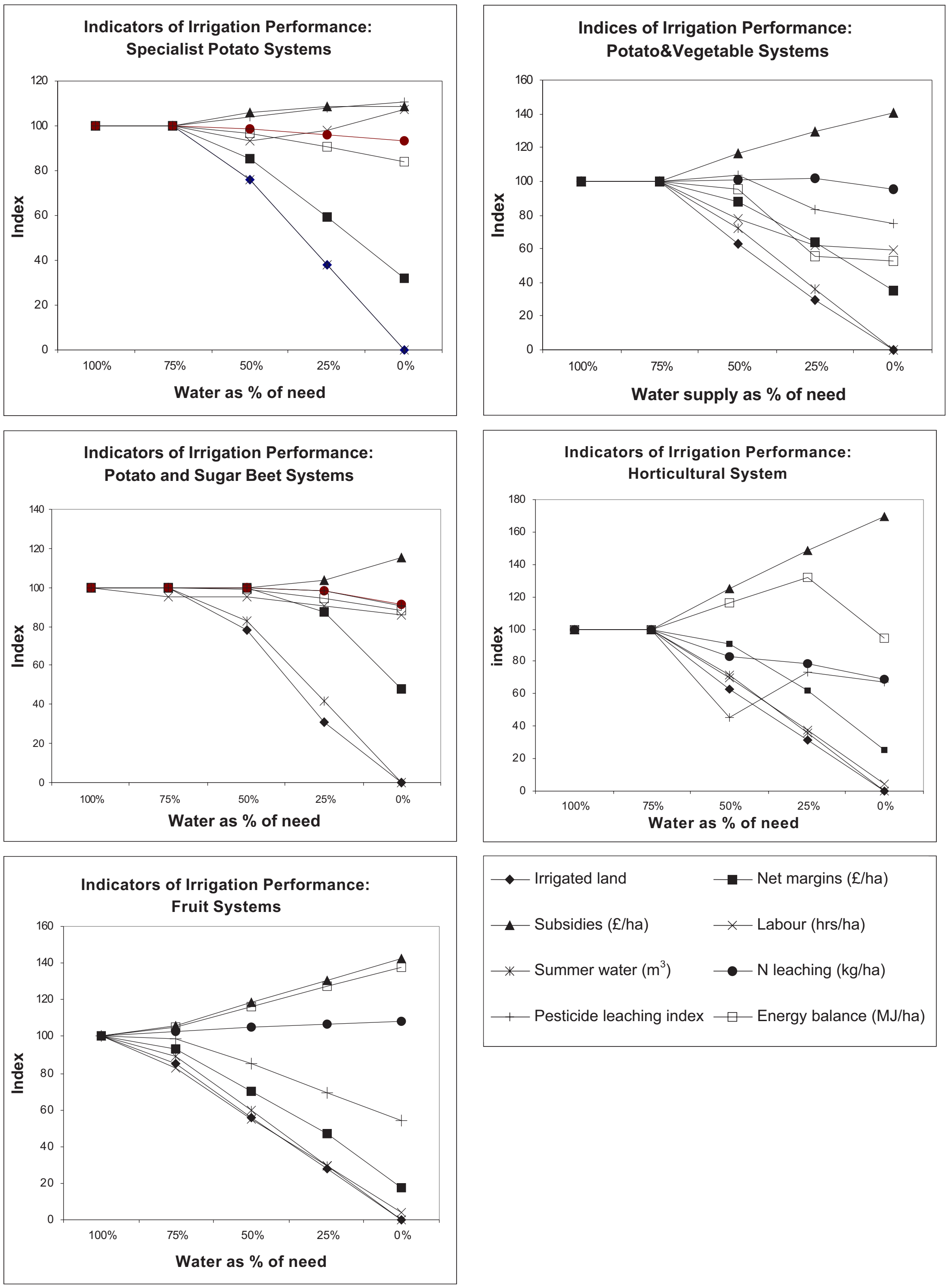


Figure 10.6. Impact of water licence quantity restrictions and abstraction charges on net margins and value added: potato and vegetable farming system

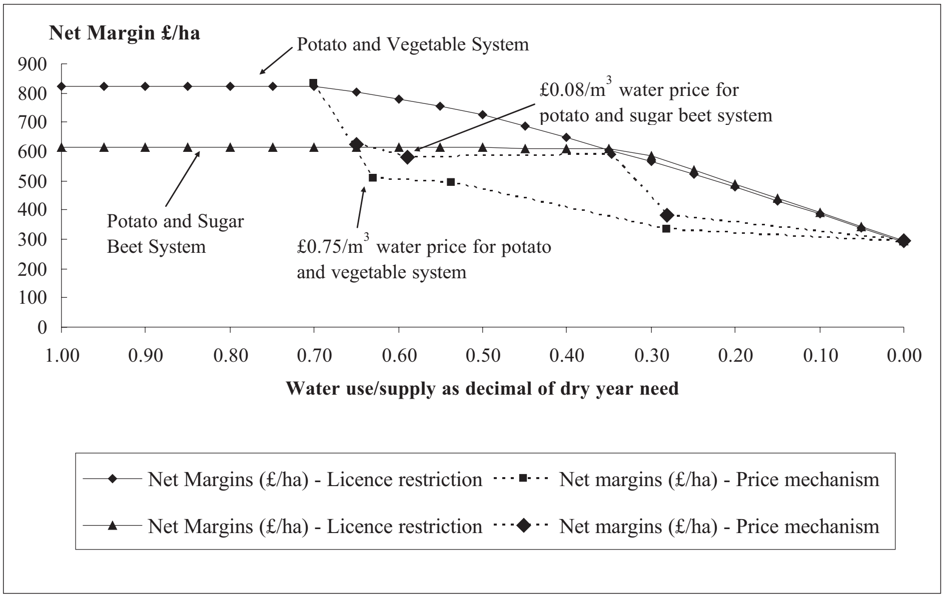


Figure 10.6 also shows the impact of policy options on the behaviour and income of potato and sugar beet farms. A 10% reduction in water use imposed through an equivalent reduction in licensed quantities available would result in a 3% fall in net margin to farmers. Due to the sensitivity to water prices on these farms, however, a 'relatively' small change in water prices would result in a significant change in water demand for sugar beet in particular. Nor would these farmers find it attractive to invest in winter storage for crops such as sugar beet.

At present, the regulating authority in the UK is not empowered to increase water charges above the cost of administering the licensing and regulation system. The main instrument is that of restrictions on abstraction licenses, especially limits on summer abstraction. Regulation may be a more effective intervention measure than increased charges if the purpose is to reduce water demand. Where demand for water is strong, there is a risk that increased water charges will have an effect on farm incomes before it would affect water consumption, certainly in the short term. There is scope however to allow trading of licenses between users, with prices set according to willingness to buy and sell. This economic instrument, set within a strong regulatory framework operating within defined hydraulic cells, would appear to be the most efficient and equitable approach to irrigation water resource management.

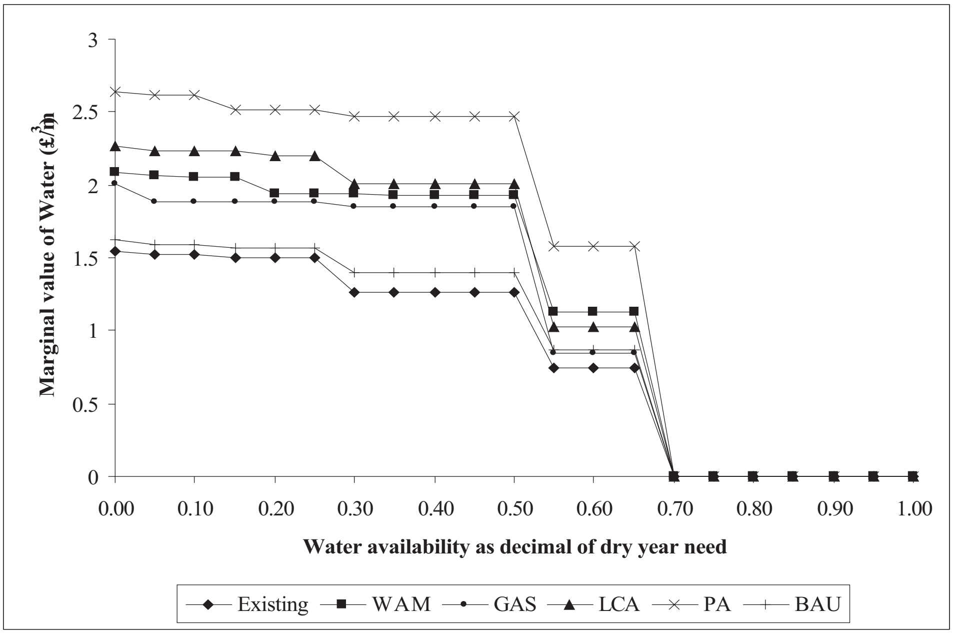
4. POLICY CHANGE AND FUTURE SCENARIOS

This section considers the impact of alternative possible futures on irrigation using scenario analysis. There are many complex relationships implicit within the scenarios which cannot be adequately accommodated at this level of enquiry. For this reason the results obtained here must be treated with much caution.

4.1. Water value

Water values tended to increase under most of the assumptions made for future scenarios due the improved relative attractiveness of irrigated crops. By way of example, figure 10.7 shows the value of water for an irrigated potato and vegetable farming system. Water values are highest under the Provincial Agriculture scenario reflecting increases in net margins for irrigated crops. Possible increases in water prices attributable to full cost recovery under the WFD would not significantly affect the viability of irrigation for most crops, except for sugar beet, and where they are irrigated, cereals and grass.

Figure 10.7. Marginal value of water under future scenarios: irrigated potato and vegetable farming system



4.2. Irrigated cropping by scenario

For the assumptions and the 10-year time frame taken, the type and area of irrigated crops for each of the farming systems showed relatively little change amongst the scenarios.

In the E&W case, irrigation crops are much less policy dependent than rainfed crops, with the notable exception of sugar beet which receives guaranteed prices within specified quota. For this reason irrigated crops retain their relative attractiveness. The irrigation of potatoes, vegetables and fruit is profitable under all scenarios, although the returns to irrigation vary.

Under all future scenarios, assuming an average rainfall year, the irrigation of sugar beet does not appear to be feasible. At present irrigated sugar beet account for 7% and 3% of the estimated irrigated area and volume of irrigation water respectively in E&W. Analysis also showed that irrigated cereals (currently 3% of the area and 1% of water volume) are not financially viable (although in the driest years cereals can recover the variable costs of irrigation where there is surplus water).

Most of the changes in cropping patterns, inputs and outputs in the future scenarios relate to the rainfed components of the scenarios. The selection of rainfed crops in any one farm model is very sensitive to their relative prices: small changes in price assumptions tend to modify the detail of rainfed crop mixtures. For this reason, the farm based indicators are not necessarily a good indicator of irrigation performance *per se* under each scenario.

4.3. Indicators of performance by scenario

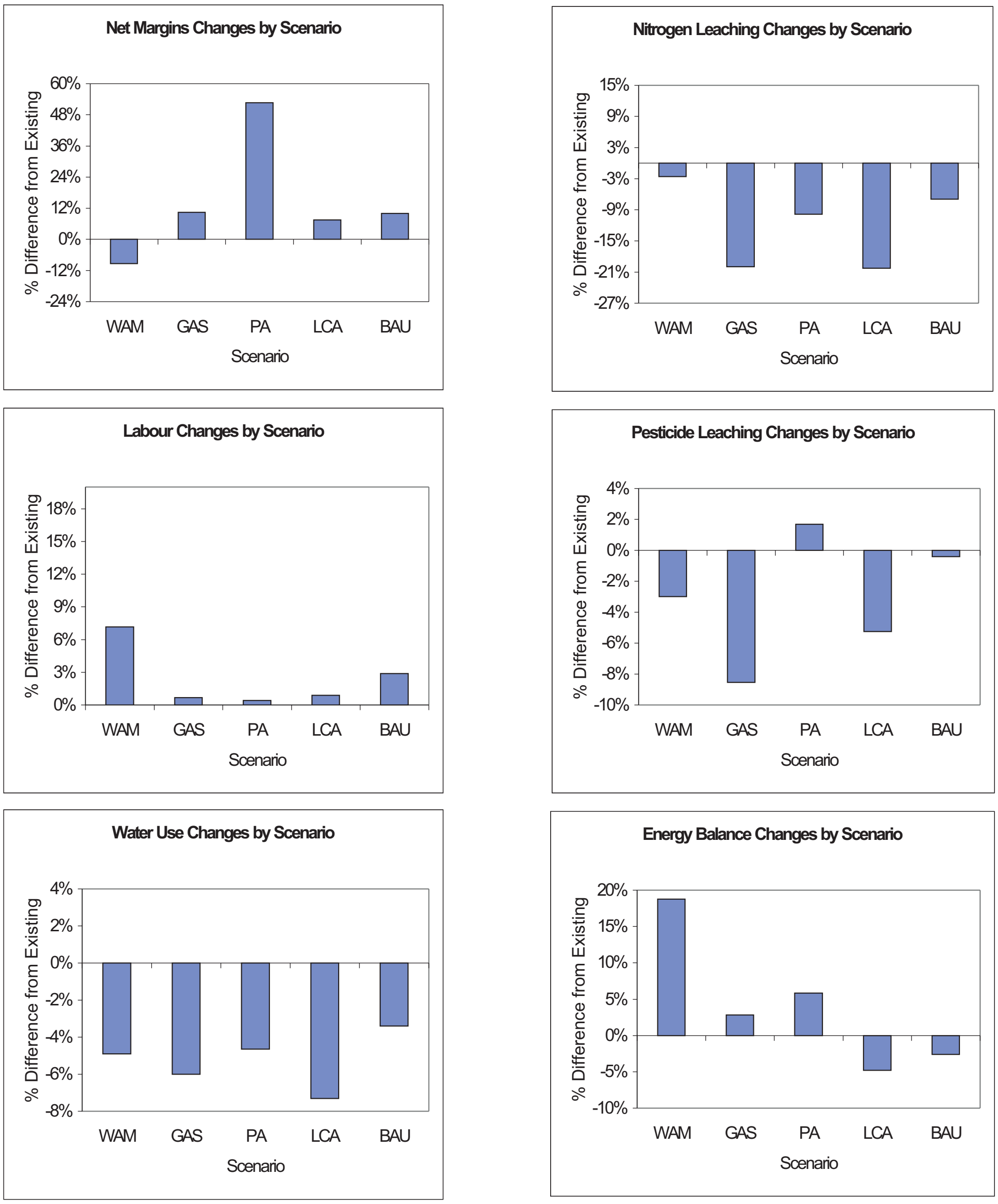
Figure 10.8 contains a summary of the indices of selected performance indicators by scenario, where the Existing scenario = 100 for each indicator. Once again the indicators require cautious interpretation because they reflect impacts on the whole farm systems of which irrigation is a part. It must also be remembered that the results are for a typical farm and do not reflect the aggregate sector level. For example, the removal of set-aside under World Agricultural Markets (WAM) will increase the cropped area on a given farm but not necessarily for the sector as a whole. This can affect the estimate of labour requirements per ha. Some of the differences between scenarios for selected indicator values, such as labour, are small and reflect small differences in cropping patterns. Caution is required in interpretation.

Taken as a whole, average net margins are greatest for Provincial Agriculture (PA) and lowest for WAM. Labour employment increases slightly under WAM but this mainly reflects changes in the rainfed cropping pattern and increased area of production per farm (but not necessarily for the sector). There is some reduction in water use per ha, reflecting different efficiencies, although application depths are expected to rise. Environmental emissions associated with nitrogen and pesticides are relatively lower under Global Agricultural Sustainability (GAS) and Local Community Agriculture (LCA) scenarios reflecting lower usage and increased control measures. Energy balance (energy out less energy in) appears greatest under WAM, but this was not always associated with higher energy efficiency (energy out per unit of energy in).

4.4. Conclusions

The irrigation sector in E&W appears relatively stable over the next 10 years, with the exception of sugar beet which is sensitive to increased irrigation costs and changes in agricultural policy. Longer term futures present a greater range of possibilities, including the prospect of climate change which, everything else remaining constant, is likely to increase crop response to irrigation but reduce water availability. Over the longer term, the differences in the parameters which describe the scenarios will deepen, such that the differences in outcomes become more apparent.

Figure 10.8 Selected indicators of irrigation performance by scenario



Indicators are expressed as averages per ha of cropping for irrigated farming systems including rainfed components.

5. NATIONAL AND REGIONAL ESTIMATES

This section contains estimates of the impact of possible policy change at the regional and national levels for E&W. Within the current enquiry, it is possible only to provide broad, indicative estimates which require cautious interpretation.

5.1. Regional irrigated areas and water use

Table 10.10 shows the distribution of irrigated crop area within and amongst regions. Anglian Region accounts for 64% of the total irrigated area, followed by the Midlands at 19% and Southern at 10%.

Table 10.10. Irrigated cropping by region, E&W, 2001

	Anglian	Midlands	Thames	Southern	North East	S West	Wales	N West	Total
Early Potato	6%	4%	2%	5%	3%	12%	20%	14%	5%
Maincrop Potato	51%	38%	60%	18%	76%	44%	59%	39%	47%
Sugar Beet	6%	16%	0%	0%	5%	4%	0%	0%	7%
Orchard Fruit	1%	1%	0%	5%	0%	0%	4%	0%	1%
Small Fruit	2%	2%	4%	6%	0%	15%	7%	0%	3%
Vegetables	25%	27%	24%	55%	8%	8%	3%	28%	27%
Grass	2%	3%	2%	6%	4%	3%	7%	7%	3%
Cereals	4%	4%	0%	1%	1%	0%	0%	0%	3%
Other Crops	5%	5%	8%	6%	1%	14%	1%	12%	5%
% within Region	100%	100%	100%	100%	100%	100%	100%	100%	100%
% amongst regions	54%	19%	6%	10%	7%	1%	1%	1%	100%

Source : Weatherhead and Danert, 2002

The regional distribution of irrigation water use follows a similar pattern to that of cropped area (table 10.11). Thames region, however, demonstrates relatively high application rates per ha of irrigation (10% of total water on 6% of the total irrigated crop area) reflecting the applications on 'other' specialist horticultural crops.

Table 10.11 Irrigation water use by region, E & W, 2001

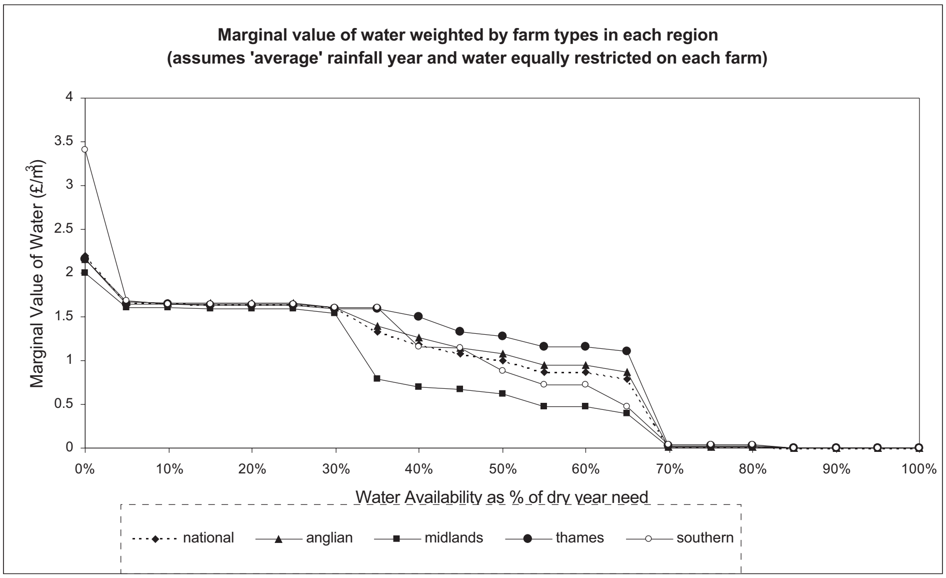
	Anglian	Midlands	Thames	Southern	North East	South West	Wales	North West	GroupTotal
Early Potato	5%	4%	1%	5%	3%	6%	14%	9%	4%
Maincrop Potato	58%	43%	65%	21%	76%	48%	60%	38%	53%
Sugar Beet	2%	10%	0%	0%	3%	4%	0%	0%	4%
Orchard Fruit	1%	0%	0%	3%	0%	0%	4%	0%	1%
Small Fruit	2%	2%	1%	6%	0%	22%	8%	0%	3%
Vegetables	25%	33%	12%	53%	8%	6%	1%	19%	26%
Grass	1%	1%	2%	3%	3%	0%	11%	13%	2%
Cereals	1%	2%	0%	0%	1%	0%	0%	0%	1%
Other Crops	5%	6%	18%	8%	5%	14%	2%	22%	7%
% volume within region	100%	100%	100%	100%	100%	100%	100%	100%	100%
% volume by region	52%	19%	10%	9%	7%	1%	1%	1%	100%

Source: Weatherhead and Danert, 2002

5.2. Regional values for water

Figure 10.9 contains estimates of the marginal value of water in the main regions of E&W, namely Anglian, Midlands, Thames and Southern based on the previous analysis of irrigation farming systems and the relative distribution of areas of irrigated crops and types of farms within the regions. The lower estimate for the Midland region reflects the relative incidence of sugar beet.

Figure 10.9. Marginal values of water by region



5.3. Future trends in crop areas and water use

Table 10.12 shows the estimated underlying annual growth rates for irrigated areas and volume of water based the period 1982 to 1995 (Weatherhead et al., 1997). The 2001 estimates confirm the underlying trends. Irrigation is increasingly concentrated on the more valuable crops. Those crops that are irrigated are being given more water.

Table 10.12. Underlying growth rates in area irrigated, average depth and total volume applied, 1982-95.

Crop category	**% change per annum on 1995 value**		
	Area	**Average Depth**	**Volume**
Early potatoes	**+1**	**+4**	**+4**
Maincrop potatoes	**+4**	**+2**	**+5**
Sugar beet	**-2**	**0**	**-1**
Orchard fruit	**-3**	**0**	**-4**
Small fruit	**-1**	**+4**	**+3**
Vegetables	**+3**	**+2**	**+4**
Grass	**-7**	**+2**	**-4**
Cereals	**-5**	**+1**	**-3**
Other crops	**+3**	**-1**	**+2**
Overall	**+1**	**+2**	**+3**

Source: Weatherhead et al., 1997

The results obtained in the analysis of individual irrigation farming systems for the Existing (Agenda 2000) and Business as Usual (BAU 2012) scenarios are consistent with and help to explain these trends. These are as follows:

- the total area of irrigated potatoes and vegetables (and therefore the relative proportion of these crops that are irrigated) is likely to increase, together with specialist cropping such as flowers and bulbs.

- the area of irrigated fruit is likely to decline, mainly due to factors affecting viability of fruit production rather than irrigation *per se*, although remaining soft fruit will have greater depths applied.
- the irrigated areas of sugar beet, cereals and grass (not considered in this study) are likely to decline, together with the volumes of water applied.
- there is likely to be small increase in the total irrigated area in the average year, but an increased total volume applied associated with substitution of cropping.
- due to restrictions on summer water, the increase in irrigation water requirements will most likely be met by winter abstraction, supported by on-farm storage.
- the cost of water will rise as a result of increase water charges, the introduction of tradeable permits, and limits on summer water which force investment in winter abstraction and on-farm storage.
- more expensive water will rule out use on low response/value crops value such as sugar beet, cereals and grass.
- sugar beet growing areas such as the Midlands will see water transferring from sugar beet to other uses, probably facilitated by trading, but the overall volumes of water transfer will be relatively small.
- for the Business as Usual scenario, economies of scale in the production and marketing of potatoes and vegetables favour an increase in the average size of the irrigation enterprise on increasingly large and specialist farms. Irrigation will be concentrated in fewer hands.

The irrigation sector does not appear to change greatly amongst the other scenarios considered in section 4 above, at least within the 10 year time frame considered here. The feasibility of irrigation of potatoes and vegetables remains robust. Over a longer time horizon, however, there could be significant differences in the way that irrigation is practiced and in the underlying characteristics of the farming systems within which irrigation takes place. Possible climate change is likely to make irrigation more attractive in E&W compared to rainfed cropping, but financial viability would depend on ability to recover the costs of winter storage of water.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Irrigation characteristics and sustainability

Although irrigation in E&W accounts for only 1.5 % of total cropped area and total water use, it is an economically important sector, associated with about 7% of the value of national crop production. It is dominated by large-scale production of potatoes and vegetables, with relatively small but locally important areas of soft fruit. Irrigation is concentrated in the relatively dry eastern part of England where the benefits of irrigation are greatest.

It appears that most irrigators have sufficient water to meet their needs in all but the driest years. However demand for summer water in some areas has outstripped supplies, such that additional water may only be obtained by means of winter abstraction and on-farm storage.

Using indicative case study farms, it was shown where rainfall is insufficient to achieve reliable quantities of high quality, high value produce, irrigation is likely to be worthwhile. The average value of irrigation water in terms of contribution to farm net margins (over and above irrigation costs excluding water) appears to be about £1.25/m^3 (1.65€/m^3), though this can vary significantly amongst crops, soil types and according to annual rainfall.This order of benefit is high by international standards, reflecting the role of supplementary irrigation for quality enhancement. The analysis here is based on many assumptions, the validity of which would need to be tested at individual farm and catchment level. Sensitivity analysis, however, suggests that the estimates are reasonably robust.

Where irrigation makes a difference to the value of crops, estimated benefits appear to be considerably greater than the costs. Average total irrigation costs range between £0.3/m^3 (0.45€/m^3) and £0.7/m^3 (1.05€/m^3) according to the need for water storage. Of this, licensed abstraction charges, currently about £0.03/m^3 (0.045€/m^3) for unsecured water supply, account for about 5% to 7% of total irrigation costs. Demand for water at these prices is not very responsive to price.

Summer water is a limitation in some areas. In the case of high value crops, this has encouraged investment in on-farm winter storage reservoirs. The analysis here confirms the financial viability of this response. Climate change is likely to increase irrigation need and other things being equal the relative advantage of irrigation. High value crops are likely to justify investment in winter storage that would be required.

With respect to performance against sustainability criteria, irrigated farming performs well in terms of financial and economic indicators: farm incomes and value added after subsidies are considerably higher than rainfed cropping in areas of irrigation need. In social terms, employment is higher and the seasonality of work is more even, often with very positive multiplier effects in the local economy. In environmental terms, irrigation has a bigger environmental impact per ha of cropping than rainfed agriculture, reflecting its relative intensity. Abstraction can affect river and ground water levels and quality during dry summers. The risk of nitrate leaching and pesticide pollution tends to be higher than cereal-based rainfed cropping, but not necessarily higher than similar crops grown under rainfed conditions. Much depends on measures taken to mitigate these risks. Irrigation is more energy intensive but the balance of energy output above input is generally higher.

6.2. Impact of agricultural policy change

For the most part the analysis showed that changes in agricultural policy tend to have a limited impact on the type and extent of irrigation in E&W compared to their impact on rainfed cropping. Irrigated crops lie mainly outside the remit of existing direct policy support. The main factors influencing the profitability of irrigation in recent years have been domestic consumer demand for quality produce, competition from imports and rising production costs. Competition from imports can of course be influenced by policy support for similar crops elsewhere in Europe and beyond. In general terms, market demand is the key driver for irrigated crops in E&W and, assuming water is available, has been the main factor controlling the extent of irrigation. Of course, these market conditions depend on a variety of social and economic factors which can change over the longer term.

The irrigation of sugar beet, which presently accounts for 7% and 3% of the irrigated area and volume of water applied respectively, is very sensitive to policy change. A relative downward change in beet prices and or an upward shift in water prices, both of which appear likely, will render beet irrigation commercially infeasible. This is happening already. In most circumstances, the irrigation of cereals is not financially viable.

6.3. Impact of changes in water policy

In the E&W case, the WFD will promote good water quality status through the use of regulatory, economic and other measures. Full cost recovery of water services will include the cost of environmental protection and mitigation with increased charges to agricultural water abstractors. Increases in water charges of 30% to 40% over the next 5 years are likely, possibly doubling over 10 years. The analysis showed that irrigation is not sensitive to this order of price increase for direct abstraction charges. Such price increases on public water however could affect the viability of this source for trickle systems on fruit. There may also be environmental charges on management practices or the use of chemicals which give rise to diffuse pollution associated with irrigation.

It seems unlikely under present legislation in E&W that charges will be made by the regulating authority for water *per se*. The analysis shows, however, that there is a strong willingness by farmers to pay more for water in order to secure supplies. Increased water prices by a water agency would have considerable and possibly unacceptable effect on the income of farmers, at least in the short term, before they led to changes in consumption behaviour. It is likely that tradeable permits will be used in areas of water deficit to promote water use efficiency by directing water to its most beneficial use. For example, water currently used by sugar beet growers could be transferred for other uses.

The WFD promotes ‘cost effective’ intervention measures to deliver ‘good ecological status’ (GES). This will require limits on abstraction to safeguard water quality, with implications for licensing and efficiency of water use. It is likely that all licenses will need to be renewed at intervals, justified against ‘economic’ need. Although the efficiency of overhead irrigation systems is relatively high, there is scope to improve scheduling.

With respect to controls on diffuse pollution, intensive irrigated agriculture will be subject to compliance with good practices and required to adopt mitigation measures to protect surface and groundwater. It is also likely that limits or bans will be placed on some agrochemicals which create a risk of ecotoxicity. This could affect crop yields. In some case integrated crop management systems can offer a solution, with extended crop rotations or use of natural methods for disease and pest control (especially for potato cyst nematode). These responses were implicit in the scenarios used in the analysis. They reduced the financial profitability of irrigation but retained its relative advantage compared to rainfed farming. For the most part, irrigated cropping of high value crops appears reasonably robust and capable of carrying the extra costs associated with WFD.

Under the WFD (as indeed under the existing catchment abstraction management planning system) limits will be placed on direct abstraction during summer where environmental quality is at risk. In future, as part of cost effective measures, there is likely to be a switch to winter abstraction and on-farm storage. The analysis here shows that this is feasible for potato and vegetable crops, and for some soft fruits. While farmers to date have largely found their own solution to water supply problems, there may be a case in future for privately funded multi-purpose regional reservoirs which include some capacity for irrigation. This could find acceptance under WFD.

With respect to derogation of heavily modified bodies, it may prove difficult in the short term to achieve GES in some water courses in intensively irrigated areas without major impacts on the rural economy. This may the case in parts of eastern England. The analysis here provides a basis for estimating the income foregone if licenses are curtailed temporarily within a season (for example by a ban on abstraction) or permanently revoked. The analysis shows that the benefits of irrigation in financial and economic terms are substantial. There may be some justification for derogation where meeting GES results in disproportionate costs, at least until appropriate solutions can be found.

6.4. Recommendations

With respect to policy makers, the analysis confirms the validity of irrigation as an economic use of water on high value crops in areas where rainfall is unreliable or insufficient. In areas of water deficit, banning the use of water for irrigation, for which there sometimes has been a call, should not be an automatic policy response. Rather, it is more appropriate to find alternative ways to meet valid irrigation requirements.

The analysis suggests that regulation in the form of quotas is probably the most effective way of managing of water use where there is pressure on total supply. Raising abstraction charges alone may not achieve the desired reductions in water consumption without unacceptable impacts on user incomes. They can however generate revenue for the water agency to fund other support mechanisms, such as local area or on-farm storage, or the development and promotion of water saving technologies. It is recommended that the practicalities of a market in tradeable abstraction licenses be explored for selected catchments within an overall quota ceiling.

It is recommended that, building on existing guidance, efforts are made to improve efficiency of use at farm level, mainly through scheduling and applications management. There is a need for adaptive research to devise locally relevant strategies for improving water use efficiency. Similarly there is a need to further promote good environmental practices amongst irrigators, but this also applies to intensive rainfed cropping. These initiatives must involve a variety of stakeholder interests: farmers, water regulators, environmental bodies, and the food industry.

Now that the implications of the WFD are becoming clearer, research is needed to confirm the links between irrigation practices and good ecological status in surface and ground waters. There will be a specific need at individual catchment level to help identify, assess and recommend cost effective measures to prevent or minimise pollution from irrigation without compromising its significant economic and social contribution. The analysis carried out here supports the recommendation that in catchments where irrigation is an important use of water, robust methodologies are developed and applied to assess the benefits of irrigation, the links between irrigation and water quality, and determine the best ways of delivering the objectives of the WFD. Such a robust assessment is all the more important given the likelihood of climate change which will further increase pressures on water resources and the water environment in the longer term.

11.

The case of Portugal

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1. Background

The objective of the WADI project is to analyse the sustainability of irrigated agriculture in Europe in the context of post Agenda 2000 agricultural policies and in the context of the implementation of the European Water Framework Directive. The approach followed to evaluate the sustainability of irrigation integrates the concepts of environmental sustainability and economic and social sustainability. This work analyses the implications that the Water Framework Directive (WFD) may have on three major irrigation regions of Portugal – Baixo Alentejo, Lezíria do Tejo and Baixo Mondego– when a volumetric tariff is applied to irrigation water under different policy scenarios.

The first sections provide a general description of the main features of agriculture and irrigated agriculture in Portugal; describes the selected study regions and characterizes some typologies within these regions; and explains the methodology used in this study. Later on the impacts of policy change, particularly concerning prospective future scenarios and the impact caused by WFD implementation via a volumetric tariff, are presented at a regionally aggregated level.

Although Portugal is not part of the Mediterranean Basis, the climate in most of the country is clearly mediterranic, with hot and dry summers and cold and wet winters. The yearly distribution pattern of average temperature and precipitation values clearly reveals the phase displacement between extreme values of temperature and precipitation of approximately six months. This means that in most of the country summer crops do not grow without irrigation.

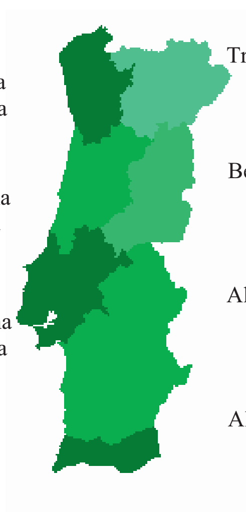
Most of the water is used in agriculture. Indeed, the use of water for irrigation purposes takes the dominant share of all uses, with 75%. When only consumptive uses are considered this share rises to 87%. Most of the water used for irrigation is pumped from surface sources, that is, directly from water courses, artificial ponds and reservoirs (INE, RGA 1989).

In general terms, the irrigated agriculture in Portugal – mainland and islands – occupies 605,348 ha, that is, 15.7% of the national Usable Agricultural Area (UAA). Looking at figure 11.1, it is very clear that this percentage hides significant disparities. The irrigated sub sector is well developed near the coast and the highest concentration of irrigated farms is concentrated in Entre Douro e Minho and Beira Litoral regions, having an irrigated UAA of 62.2 and 53.9% of their respective UAA. In the interior part of the country, the irrigated areas range from 6.1 % in the Alentejo region and slightly above thirteen percent in Beira Interior and Trás-os-Montes regions.

The average irrigated UAA per irrigable farm is usually very small in almost all areas, varying between 1.3 and 2.0 ha/farm in Beira Litoral and Entre Douro e Minho. This index reaches the maximum values for Lisboa and Vale do Tejo and Alentejo, with 3.8 and 8.4 ha/farm. Considering the UAA/Farm and Irrigated UAA/Irrigated Farm indexes, this aggregated data seems to indicate that the use of water for irrigation purposes is used as a substitute for land.

As far as the most significant irrigated crops are concerned, it is possible to see in the following table that maize (hybrid and regional) is clearly the dominant temporary irrigated crop, accounting for more then 16% of the national irrigated area. Altogether, animal feeding crops such as pastures, silage and fodder crops occupy 32% of the irrigated area. Orchards and potatoes occupy less then 5.5% and 6.1% of the area, and other crops do not have significant area.

Figure 11.1. Irrigated area in each agricultural regions



When disaggregating these values according to their origin, it is possible to see that most animal feed crops are grown in the northern part of the country (Entre Douro e Minho, Trás-os-Montes, Beira Litoral and Beira Interior); that potatoes and orchards are concentrated in trás-os-Montes and Beiras. Furthermore, it is clear that some other crops have a very strong regional significance, such as rice, industry tomatoes and vegetable crops in Lisboa e Vale do Tejo region, and such as rice and sunflower in the Alentejo region or citrus production in the Algarve region.

Table 11.1. Most important irrigated crops in each agricultural region

Irrigated Crops (regional %)	Portugal	Entre Douro e Minho	Trás -os- Montes	Beira Litoral	Beira Interior	Lisboa e Vale do Tejo	Alentejo	Algarve
Durum Wheat	--	--	--	--	--	--	7.8	--
Hibrid Maize	16.1	16.1	--	20.6	4.9	28.2	19.3	--
Regional Maize	7.9	13.6	8.8	14.9	14.0	--	--	--
Rice	--	--	--	7.0	--	7.6	9.2	--
Silage Maize	9.2	26.1	--	11.6	--	--	--	--
Fodder Maize	--	--	--	--	22.4	--	--	--
Other Fodder Crops	9.5	13.9	--	12.5	15.9	4.9	8.5	--
Potatoes	6.1	--	15.4	9.9	7.7	--	--	--
Sunflower	--	--	--	--	--	--	10.5	--
Industry Tomatoes	--	--	--	--	--	9.5	--	--
Vegetables	--	--	--	--	--	11.3	--	--
Permanent Pastures	7.8	--	42.0	--	8.3	--	--	--
Orchards	5.4	--	10.4	--	9.9	9.6	--	7.0
Citrus	--	--	--	--	--	--	--	66.9
Vineyards (wine)	--	5.5	--	--	--	--	--	--
Olive Groves	--	--	6.6	--	--	--	6.5	--

Based on INE, 1999

Bearing in mind the objectives of the WADI project we have tried to identify the most important irrigated regions in Portugal. The main idea is, on the one hand, to characterize the most diverse situations in order to identify the actual irrigation problems, and on the other hand to find representative regions that allow us to correctly forecast the real impacts of CAP evolution and the Water Framework Directive. Interviews with experts and statistical information was consulted to correctly identify these regions.

As mentioned above, with regard to the structural characteristics of farms or crop patterns and because of climate and soil factors as well, it is advisable to divide the country into North and South. For social and development reasons, we must distinguish between the interior and coastal regions. We have therefore considered the following areas, as illustrated in the map below:

Table 11.2. Irrigated area in each studied zone

Region	UAA (ha)	Irrigable Area (ha)	Irrigable Area (%)
Baixo Alentejo	612,540	39,357	6.4
Lezíria do Tejo	220,209	85,981	39.0
Baixo Mondego	43,375	26,619	61.4

Based in INE, RGA. 1999

Figure 11.2. Location of the irrigated areas.

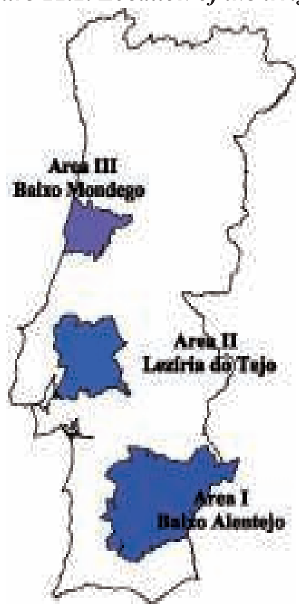


Table 11.3. Most important crops in each study area

Irrigated Crops (regional %)	Baixo Alentejo	Lezíria do Tejo	Baixo Mondego
Common Wheat	17.8	--	--
Durum Wheat	8.9	--	-
Hibrid Maize	13.8	38.0	32.4
Rice	--	12.0	21.7
Silage Maize	--	--	15.5
Other Fodder Crops	--	--	7.9
Potatoes	--	--	6.3
Sugar Beet	--	5.5	--
Sunflower	13.9	--	--
Industry Tomatoes	--	14.0	-
Olive Groves	7.1	--	--
Others	12.2	--	--

2. CASE STUDY DESCRIPTION, CLUSTERS DEFINITION

The identification and selection of different farm typologies was achieved through literature review, statistical data analysis, particularly concerning technical-economic orientation, and consultation with experts. Relevant typologies are defined considering both crop pattern and farm size.

The irrigated agriculture in these areas is further disaggregated and analysed into irrigation sub-sectors, differentiated by type of crop and farming area. In the case of Baixo Alentejo these sub-sectors consist of a Vegetables typology, a General Agriculture typology and an Extensive Farming typology. In the Lezíria do Tejo region only two typologies were considered relevant. For Baixo Mondego just one typology is sufficient to characterize the main agricultural system of this region. Once the implications of policy change in each particular typology are determined, the results are aggregated at the regional level bearing in mind the existing area relevant to those typologies.

2.1. Baixo Alentejo Region

Baixo Alentejo is a part of the wider area called Alentejo. Baixo Alentejo represents almost thirteen per cent of the total surface area of the country and sixteen per cent of the Useable Agricultural Area. This region has 2080 irrigable farms and 39357 ha of irrigable surface, which occupy 6.4% of this region UAA. In this large region of the country, summer crops do not grow without irrigation. Traditionally, this is a region of large farms growing winter crops, namely cereals. Almost the entire surface is utilized in agriculture, growing predominantly temporary crops and permanent pastures. A large majority of the land and farms is held by individual producers. Landowners hold two thirds of the UAA, and about one third is rented to other producers. The farm's land structure is composed of large farms, averaging 65ha per farm, concentrated on few blocks.

In this region three different typologies are analysed, which are thought to be together capable of providing a good description of this region irrigated agriculture. A Vegetables typology represents small irrigated farms where very intensive crops such as vegetables and processing tomatoes are predominant. An Extensive Farming typology designates a very common transition situation in this region; although these farms are equipped with irrigation systems and there is water available, agricultural systems remain similar to those characteristic of rain fed ones, that is, based on extensive cereal farming. The last typology considered in this region is designated General Agriculture, which corresponds to an in-between situation of the previous typologies. It comprises a non intensive component of vegetable crops as well as a component of cereals.

Table 11.4. Identification of Baixo Alentejo typologies

Main Crops (ha)	Typologies Baixo Alentejo		
	Vegetables	General Agriculture	Extensive Farming
Sweet Pepper	0.36		
Tomato (fresco)	0.24		
Lettuce	0.14		
Onions	0.36		
Broccoli	0.18		
Melon	3.51	2.00	
Tomato (Industry)	5.20	3.34	
Common Wheat		12.59	28.20
Durum Wheat		6.32	14.20
Maize		9.74	21.80
Sugar Beet		2.29	5.20
Sun Flower		9.87	22.00
Set Aside		3.85	8.60
Area (ha)	10.0	50.0	100.0

Table 11.5. Relevance of Baixo Alentejo typologies (in percentage)

0.452	Extensive Farming
0.517	General Agriculture
0.031	Vegetables

In order to identify general trends due to policy change, the implications for farm income, agricultural labour demand, water consumption and several other indicators are aggregated at regional level. According to this regional statistical data concerning selected irrigated crops it is possible to determine the relevance of each typology, and so the participation (weight) of each typology in the aggregated region is determined. Regional values correspond to the horizontal summation of each typology result affected by the previous coefficient. Although being of extreme importance, the contribution of vegetable activities in this area is insignificant when the results are grossed.

It should be noted that the base data which supports the aggregation coefficients is for the year 1999. Acting on this, future aggregated scenarios incorporate the present allocations of crops, which in their turn, reflects existing relative prices and input-output relations.

2.2. Lezíria do Tejo Region

Lezíria do Tejo is a part of the Lisboa and Vale do Tejo region. It is located in the most developed part of the country, from almost all points of view. Given the existence of good and flat soils associated with good levels of technology and a long tradition of irrigation, agriculture is a very important activity in this area and irrigated crops represent the most important part of agriculture. Lezíria do Tejo region accounts for 6.8% of the total surface and 5.7% of the Useable Agricultural Area. About two thirds of all surface area is utilized for agriculture, the last third being exploited for wood and forestry uses. 46.5% of the UAA is allocated to arable land situations (temporary crops, set-aside and family horticulture) growing cereals, temporary pastures and fodder crops. Processing crops such as sugar beet and industry tomatoes are very important in this area. There are 85,981 irrigable hectares distributed within 7,507 irrigable farms. The irrigable area represents 39.0% of the regional UAA.

The study of Lezíria do Tejo region is based on only two typologies of farms. In order to facilitate comparability among typologies of different regions, the typologies of this region are Vegetables and General Agriculture. Nevertheless, it is important to highlight that the intensity of crop patterns is far greater than in Baixo Alentejo.

Table 11.6. Identification of Lezíria do Tejo

Main Crops (ha)	**Typologies Lezíria do Tejo**	
	Vegetables	**General Agriculture**
Maize		12.95
Rice		4.09
Sugar Beet		1.89
Set Aside		1.30
Tomato (Proc.)	3.71	4.78
Lettuce	0.27	
Melon	0.33	
Sweet Pepper	0.16	
Tomato (Fresh)	0.15	
Onions	0.15	
Carrots	0.22	
Area (ha)	5.0	25.0

Table 11.7. Relevance of Lezíria do Tejo typologies (in percentage)

0.795	General Agriculture
0.205	Vegetables

In this region, the cultivation of vegetables is much more important then in Baixo Alentejo. The coefficients used to calculate the regional impact show that the irrigated sector is divided into 20.5% for vegetables and 79.5% for several other kinds of irrigated activities.

2.3. Baixo Mondego Region

Baixo Mondego is integrated in the Beira Litoral region. It gets its name from the Mondego River, which is the most important river that springs in Portugal. It is located in the Northern litoral part of the country, where farms are small or very small and each firm has a lot of small and irregular holdings. These characteristics make irrigation difficult and costly. Irrigated crops, manly corn and rice, have a long tradition in this area. The Baixo Mondego region has 1.3% of the total national surface area, and accounts for 1.1% of the UAA. Most of the UAA is utilized in arable crops; the large majority (93%) is utilized for temporary crops, namely cereals, temporary pastures and fodder crops. 61.4% of this region UAA is irrigable by 15043 farms with, on average, 1.8 ha.

Table 11.8. Identification of Baixo Mondego typology

Main Crops (ha)	Typology Baixo Mondego
Maize	4.02
Rice	2.35
Silage Maize	1.69
Other Fodder	0.86
Potatoes	0.68
Set Aside	0.40
Area (ha)	10.0

In Baixo Mondego it would not be significantly relevant to model more then one type of typology. It is believed that farmers and farms in this region are quite homogeneous from the dimension point of view, that is, with farms of very small and medium size, dependent mostly on rice, maize and on fodder crops as well. As such, this typology results correspond to this area regional results.

3. METHODOLOGY

The main objectives of the models used in this research are to quantify the economic, social and environmental impacts of implementing the Water Framework Directive (WFD), in the main irrigated regions of Portugal, under different scenarios of agricultural policies.

The analysis of policy effects followed in this study is performed using a Multi-Objective mathematical programming model (Multi-Criteria Decision Making Theory) combined with goal-programming techniques, in order to construct a multi-attribute utility function consistent with the actual farmers' preferences. This is accomplished by using an approach that tries to characterize farmers' behaviour patterns, considering the empirical objectives of maximizing farm income (entrepreneurial and land revenue) and minimizing risk, employment and operative capital. These mathematical models reproduce farmers' behavioural patterns and allow forecasting of the consequences of agricultural and water-pricing policy change (for more detail please consult the methodology section in Part I).

4. WATER DEMAND AND WATER PRICING IMPACT ON AGRICULTURAL SYSTEMS

The following table presents the present status of the irrigated agriculture in each region using an extended set of sustainability indicators. Later particular comments are made concerning the consequences of water pricing for regionally aggregated results.

Table 11.9. Present Agenda 2000 assessment (null water price)

	Baixo Alentejo				Lezíria do Tejo			Baixo Mondego
	Vegetables	**General Agriculture**	**Extensive Farming**	**Aggregated Value**	**Vegetables**	**General Agriculture**	**Aggregated Value**	**Baixo Mondego**
Farm Income (€/ha)	2573.9	812.2	672.1	803.5	3264.9	1030.6	1488.6	702.5
Support – Direct payments (€/ha)	0.0	302.2	141.0	220.0	0.0	325.1	258.5	357
GDP (€/ha)	2573.9	510.0	296.9	477.7	3264.9	705.5	1230.2	345.5
Total Labour (AWU[9]/ha)	0.132	0.029	0.009	0.023	0.283	0.045	0.094	0.030
Seasonality – Positive Deviations (%)	51.7	45.1	32.1	39.4	52.2	44.0	45.7	39.5
Water Use (m^3/ha)	5202.5	2770.7	2932.6	2919.3	4915.0	6124.2	5876.3	8284
Nitrogen Use Intensity (Kg/ha)	116.1	124.1	141.0	131.5	115.1	142.2	136.6	167.4
Pesticide Use Intensity (/ha) - LD_{50}	71117.7	13589.2	12160.2	14726.7	22707.4	27528.8	26540.4	71970.9

4.1. Baixo Alentejo – Aggregated results

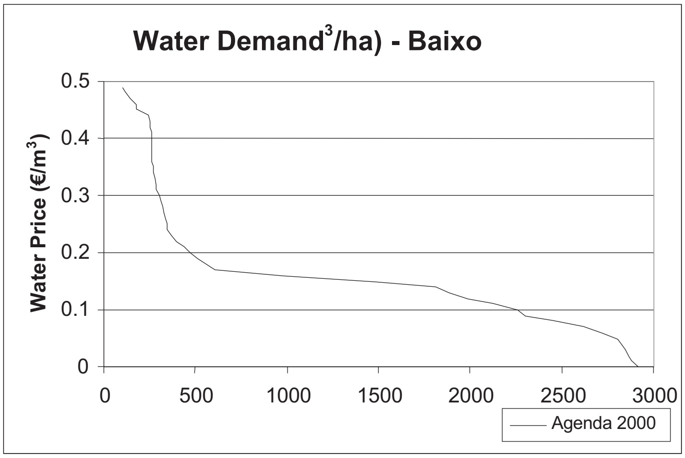
The aggregated results were obtained by weighing the respective values for the different agricultural typologies. The weights are the area occupied by each typology.

4.1.1.- *Water Demand (m^3/ha)*

As would be expected, the aggregated results of Baixo Alentejo region are comprised of the General Agriculture and Extensive Farming typologies. The maximum average water consumption per hectare is calculated to be 2919.3 m^3/ha, attained at a free water situation. These weighted results indicate that for water prices below 0.05 €/m^3 the demand for irrigation water is not likely to be elastic, in fact, at the mentioned price the diminishment response is 3.8% of the initial value. Setting the water price to higher values would represent very strong reductions in consumption. For instance, between 0.05 and 0.14 €/m^3, the water demand average reduction would be of 111 cubic meters per each Euro cent increase and, would even rise to 313.2 m^3/0.01€ for the range of 0.14 to 0.18€/m^3. At this latter price the water consumption is reduced to 555.1 m^3/ha, which represents only 19.0% of the original demand. For higher water prices further significant reductions are not expected as the curve is not very elastic.

[9] - One Annual Working Unit (AWU) corresponds to the amount of labour that a permanent employee produces during one year, working eight hours per day, during 275 days.

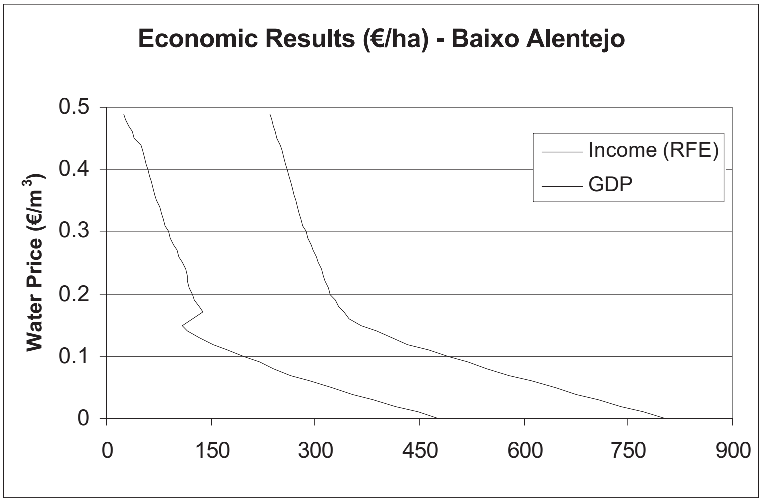
Figure 11.3. Aggregated irrigation water demand curve for Baixo Alentejo



4.1.2.- *Economic balance*

In general, the economic balance of vegetable farms is quite good. But as these farms have a very reduced contribution to the irrigated farms of this area, the resulting economic balance varies from low to very low. The state support allocated to this region has a very important and decisive role to play, as when the water price is increased, the main trend of public funds spent on agriculture is of a relative rise, although decreasing in absolute terms. At zero water price the state support already contributes 40.5% of farm income.

Figure 11.4. Baixo Alentejo economic results: Income and GDP



The economic balance, although positive, is low and sharply decrease for water prices between zero and 0.17 €/m^3. The highest value of farm income which is 803.5 €/ha is verified at a zero water price situation. A water price of 0.05 €/m^3 would bring down the farm income by 158.3 €/ha, which corresponds to a 19.7% loss. Doubling the water price level would almost double the loss of income. Setting the water price at 0.15 Euro per cubic meter would represent a reduction of 437.7 €/ha (an almost 55% reduction). Along the 0.00-0.17 €/m^3

segment the average reduction in farm income is expected to amount 27.2 € per each cent increase of water prices. At the end of this segment the public funding contribution is already at 59.5%.

Beyond this price interval the economic results are not severely affected. Nevertheless, the reduction tendency continues and at the end of the simulation (0.49 €/m^3) the farm income is only 29.2% of the original amount and state support reaches 89.6% of farm income.

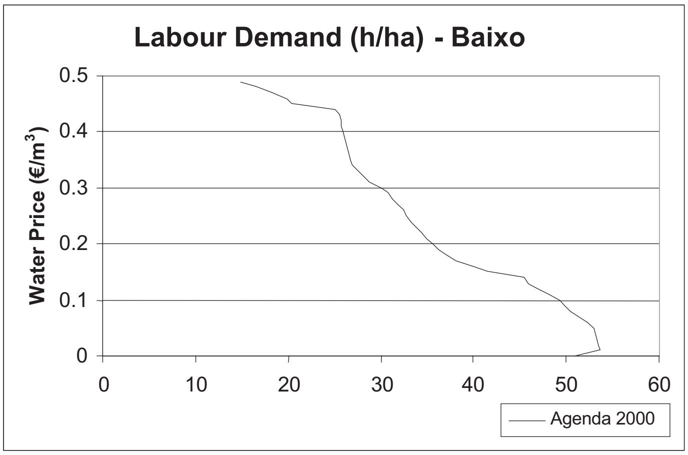
It is worthwhile to note that, especially for low water prices (below 0.10 €/m^3), the result is more an effect on farm income than on a reduction in consumption. That is to say that farmers are more likely to suffer the consequences of an increase in the water price, than to change their behavioural habits and produce more water saving crops.

4.1.3.- *Social impact*

The maximum aggregated amount of employment per hectare generated in this region under the present Agenda 2000 policy is of 0.024 AWU (53.7 h/ha). As the demand for labour is progressively less as the water price increases, at 0.10 €/m^3 the demand is only slightly reduced, but at a water price of 0.20 €/m^3 about thirty per cent of those labour units would no longer be required, that is, minus 15.3 h/ha.

At the end of the simulation (0.49 €/m^3) 70.8 % of the initial labour needs would be gone – that means that per each 61 irrigated hectares of land in Baixo Alentejo, one full time employee would be dismissed. In other words, from the initial labour demand per hectare only 29.2% is needed across the entire range of simulated water prices.

Figure 11.5. Aggregated agricultural labour demand curve for Baixo Alentejo



4.1.4.- *Environmental impact*

As far as the environmental impact associated with policy change is concerned it is possible to analyse the nitrogen inputs and a pesticide intensity indicator. On environmental grounds the implications of applying WFD seem to be very promising under this agricultural policy regime. For these indicators the progressive reductions are significant from a one cent increase in water price. Near the water prices of 0.16 €/m^3 and 0.17 €/m^3 these indicators are already reduced by half.

4.2. Lezíria do Tejo – Aggregated results

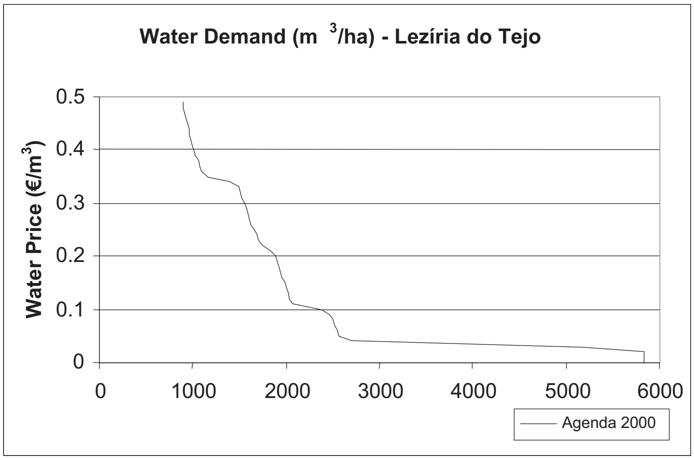
4.2.1.- *Water demand (m^3/ha)*

Resembling the vegetables typology in the Baixo do Tejo region, the water demand function of the same typology in Lezíria do Tejo is not very elastic for low water prices; but contrarily to that situation, the contribution of the vegetables typology to this region aggregated results is much more relevant.

The aggregated water consumption in this region is high or very high, particularly for low water prices. Starting from a very high consumption of 5837.2 m^3/ha, at zero water prices, it sharply decreases by more than half at a water price of four Euro cents per cubic meter. The justification for this occurrence lies in the fact that the type of crops produced at such prices is very water consumptive, namely rice and maize. Therefore, the water demand function of this region has, usually, high consumption values for low prices of water, immediately followed by sharp reductions.

For water prices above those mentioned, water demand starts to decrease at more moderate rates, and at a water price of 0.10 €/m^3 the reduction is calculated at 59.1%, and at 0.20 €/m^3 is 67.7%. The simulation ends at the 0.49 €/m^3 water price with a water demand of 901.8 m^3/ha, that is, 15.4% of the original consumption.

Figure 11.6. Aggregated irrigation water demand curve for Lezíria do Tejo

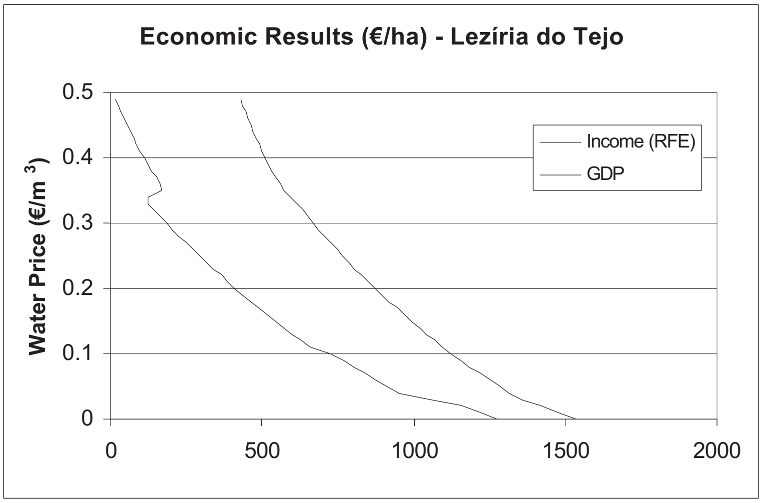


4.2.2.- *Economic balance*

Although the GDP of the General Agriculture typology is negative beyond a water price of 0.18 €/m^3, the aggregated economic balance is always positive in this region, showing high to medium-high farm incomes. Public funds allocated to this region exhibit an increasing tendency, both in relative and absolute terms.

The highest farm income is reached at a zero water pricing with the value of 1533.4 €/ha. At five Euro cent per cubic meter of water farm income is reduced by 16.3% to a value of 1284.1 €/ha. It is worth noticing that at this price level, the accumulated water savings are reduced by 56%. In fact, this is the most water responsive price which simultaneously inflicts less damage to farm incomes.

Figure 11.7. Lezíria do Tejo aggregated economic results: Income and GDP



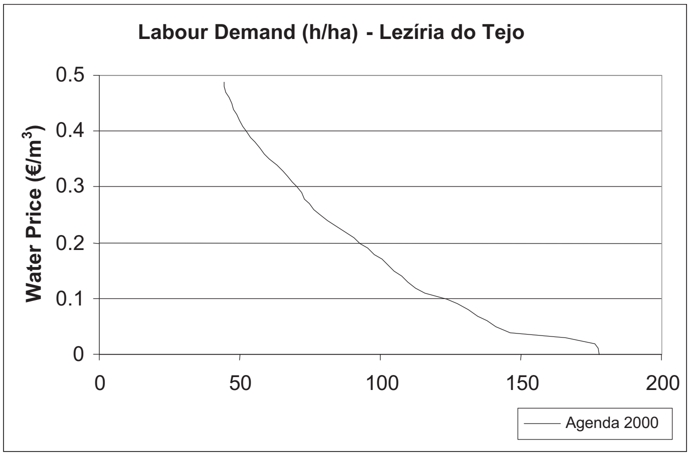
From the 0.05 €/m^3 price onwards to 0.35 €/m^3 the farm income curve is approximately equally curved, with an average loss of farm incomes of twenty four Euros per each cent increase on water prices. At the 0.35 €/m^3 level the farm income is already reduced by 960.9 €/ha to a value of 572.5 €/ha, which corresponds to a 62.7% loss.

For water prices above 0.34 €/m^3, the amount of payment for water services is higher than the public funds allocation to this region. This is to say that for water prices below this, this water-pricing policy method would basically consist of a transfer from the agricultural budget to a water agency via irrigated farmers. In fact, during the entire range of the simulation, the aggregated results indicate that per each cent increase in water prices the public funds allocated to this typology are on average increased by 3.1 €/ha. Public contribution to farm incomes begins with a value of 258.5 €/ha, which represents a contribution of 16.9% and reaches 96% of farm income at the end of the parameterisation with a contribution of 410.9 €/ha. The highest value of public support is attained at a water price of 0.33 €/m^3, at 491.6 €/ha.

4.2.3.- *Social impact*

If, on the one hand, it is in the first four Euro cents increase of water prices that the amount of water savings are more noticeable and the loss of income is not too great, on the other hand, the agricultural labour demand is reduced by 18.0%, which corresponds to 32 hours per hectare. Water prices above this, progressively promote on average the elimination of 2.3 h/ha per each Euro cent increase of the water price, at a more or less constant rate. As such, at water prices of 0.10 €/m^3 and 0.20 €/m^3, the amount of labour that is no longer required amounts to 30.8% and 47.9% (less 54.9 h/ha and 85.4 h/ha), respectively. Expressing these results in number of full time agricultural employees, setting water prices to 0.10 €/m^3 or 0.20 €/m^3 would mean that the demand for labour would be reduced by one person per each 40.1 ha and 25.8 ha.

Figure 11.8. Aggregated agricultural labour demand curve for Lezíria do Tejo



4.2.4.- *Environmental impact*

The aggregated pesticide risk indicator for this region shows a very clear decreasing tendency. From an initial value of 29,315.5 it is reduced to 19,171.8, for a water price of 0.10 €/m^3, to 5,293.0 at 0.20 €/m^3, and from this price until the simulation end it is further reduced by 1,766.3 units. With an inverse tendency, the N input indicator shows a slight increase (from 139.5 Kg/ha at null water prices to 143.9 Kg/ha at 0.17 €/m^3). For very high water prices, above 0.33 €/m^3 it is very likely that N inputs tend to suffer some decrease, the results indicate that the minimum value of N applications is of 102 nitrogen units per hectare near the end of the water price parametrization.

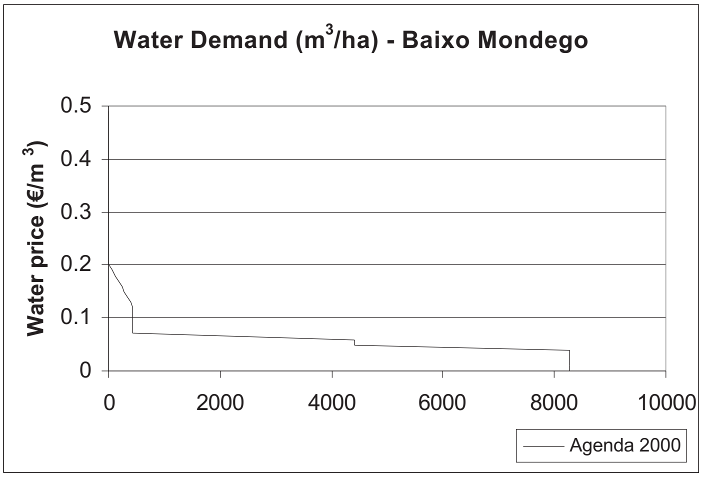
4.3. Baixo Mondego – Aggregated results

4.3.1.- *Water demand (m^3/ha)*

The water demand in the Baixo Mondego typology is very high. Not surprisingly, this has to do with the large amount of surface allocated to rice and maize production, both very water demanding activities. As in the previous region this high value of water demand rapidly decreases as the water price increases.

The consumption of water is 8,284 m^3/ha at the zero water price, and stays unchanged until the water price reaches five Euro cents per cubic meter. In fact, at a price of 0.05 €/m^3 rice paddies are abandoned and the water consumption decreases by 3,877 m^3/ha, which correspond to a reduction of 46.8% of the initial value. At a water price of 0.07 €/m^3, maize production disappears. The water demand is then brought close to insignificant amounts, with 446.7 m^3/ha. The demand for irrigation water absolutely ceases at the water price of 0.21€/m^3.

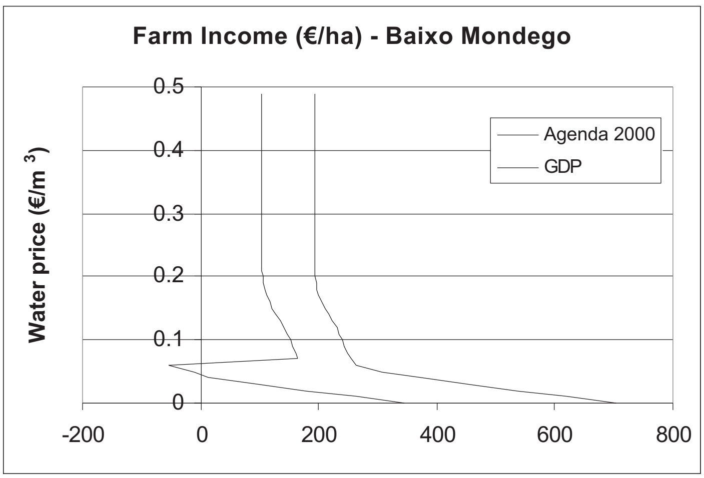
Figure 11.9. Aggregated irrigation water demand curve for Lezíria do Tejo



4.3.2.- *Economic balance*

In spite of the high water consumption, farm income is low and state funding provides a quite significant support to farm incomes, varying from 121.1% to 34.9%, at water prices of 0.06 €/m^3 and 0.07 €/m^3. The farm contribution to GDP is also usually very low, varying from 345.5 €/ha (at the zero water price level) and minus 55.5 €/ha. The highest farm income value is obtained in a non water pricing situation amounting 702.5 €/ha and it is rapidly reduced, which matches the water consumption trend. At five Euro cents per cubic meter the income loss is already close to 56.3%. At a water price of 0.10 €/m^3 only 34.2% of the original income is achieved. At a water price of 0.21 €/m^3 the income reduction would be 72.4%, exclusively coming from rain fed agriculture activities.

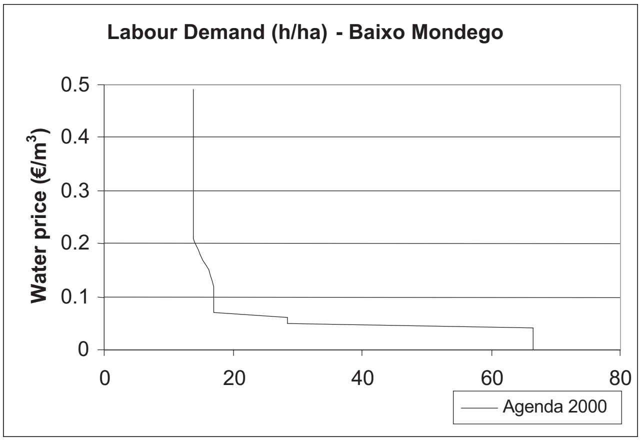
Figure 11.10. Baixo Mondego aggregated economic results: Income and GDP



4.3.3.- *Social impact*

The social impact of applying a water policy is very severe. It is possible to note that the amount of agricultural labour demand is strongly influenced by the type of crops grown. As soon as rice is eliminated the demand for labour decreases to 42.9%, that is, a reduction of 38 h/ha. At a water price of 0.07 €/m^3 the employment necessary suffers a decrease of 74.3% (that is, one full time employee less per each 45 ha).

Figure 11.11. Aggregated agricultural labour demand curve for Baixo Mondego



4.3.4.- *Environmental impact*

Both environmental indicators, nitrogen and pesticide risk, exhibit a reduction in similar patterns to those of water demand, social impact and income.

5. RESULTS BY SCENARIO OF WATER DEMAND AND OTHER INDICATORS

For the purpose of modelling the impact of policy change in the irrigated agriculture sub-sector, evolution scenarios are analysed, considering the time horizon as being the year 2010. Scenarios are statements of what might possibly happen; policy scenarios used in these models are to be understood as prospective futures rather than predictive.

The four scenarios which were modelled in this study are World Markets, Global Sustainability, Provincial Enterprise and Local Stewardship (Adopted from Morris and Vasileiou, 2003; based on Foresight, 1999) (for more detail please consult the scenarios section in Part I)

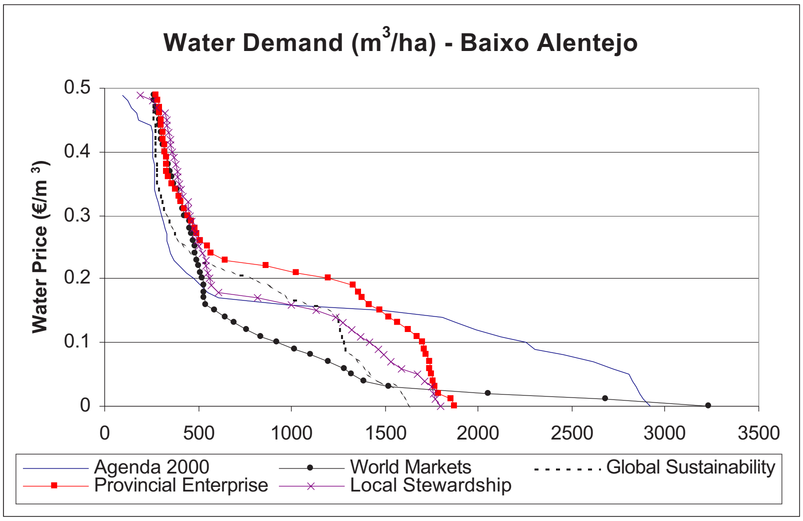
5.1. Baixo Alentejo – Agricultural policy scenarios

5.1.1.- *Water demand (m^3/ha)*

Future scenarios are intended to be merely prospective, they are not deterministic realities. Therefore, the results of these scenarios should be understood as feasible and likely interval ranges.

The present Agenda 2000 scenario is a policy situation that exhibits very high water consumption and that is shown to be quite resistant during the first steps of water pricing. In fact, the most significant water savings are situated in the water price interval between 0.14 €/m^3 and 0.17 €/m^3. On the opposite evolution, for water demand, is the World Market scenario. It is seen to be very elastic for very low prices of water. Indeed, at a water price of four Euro cents per cubic meter the water savings already amount to 57.1%. All remaining scenarios have identical evolutions, presenting a maximum demand for water below 2000 m^3/h, being slightly reduced until water prices reach around 0.15 €/m^3 and 0.20 €/m^3, where the most significant reductions are registered.

Figure 11.12. Aggregated water demand curve for Baixo Alentejo under different agricultural policy scenarios

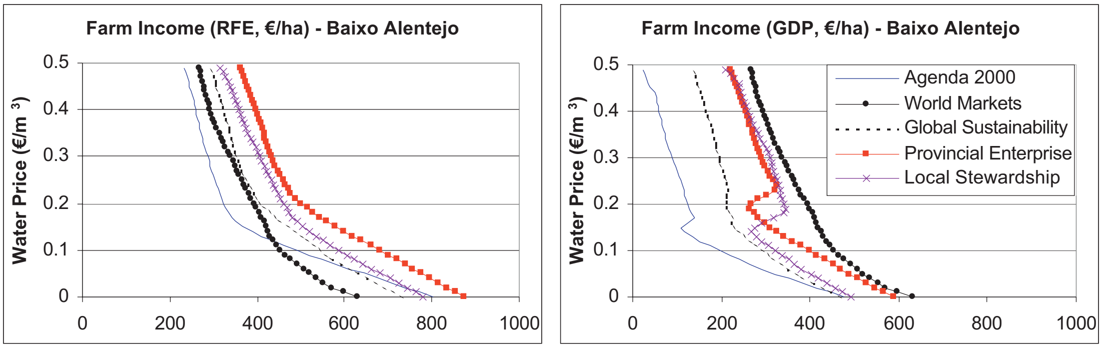


5.1.2.- *Economic balance*

As far as farm income is concerned, it is possible to see (figure 11.13) that the Agenda 2000 is one of the worst scenarios. In comparison, these poor results are only lowest in the agricultural liberalization scenario for water prices below 0.12 €/m^3. In this last scenario it should be highlighted that the contribution to the GDP is always the highest of all scenarios (the difference between RFE and GDP corresponds to the public funding allocated as direct subsidies). If in the left-hand graph the curves are alligned almost in parallel, in the right-hand figure it is noticeable that the weight of public funds often has a contribution of more then half the farm income.

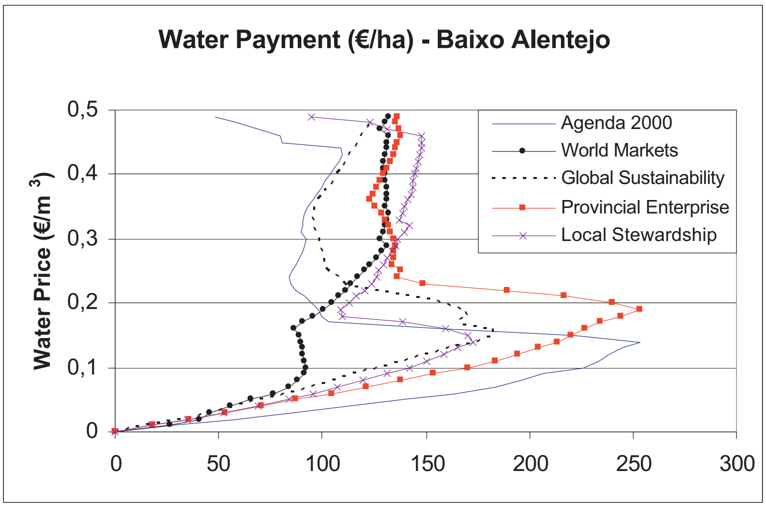
As far as water payment to (water receipts of) a water management institution is concerned, it should be noted that the amount of funds firstly increases when the water price is increased and water consumptions are still high, and then suffers a strong reduction when high water prices reduces water demands.

Figure 11.13. Aggregated economic results in Baixo Alentejo under different agricultural policy scenarios: income and GDP



The aggregated crop-mix chosen by the models to integrate each level of water price assures the highest amount for water payments in the Agenda 2000 policies; on the other hand, it is also in this scenario that the water receipts are cut back at earlier stages of the water price.

Figure 11.14. Aggregated water payments in Baixo Alentejo under different agricultural policy scenarios

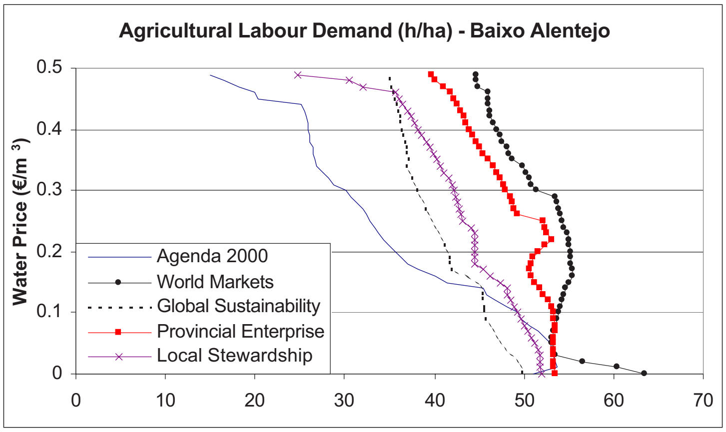


In the World Market scenario, the comparatively reduced competitiveness of most commodities in this region because of very low water prices forces the crop-mix to be changed to less water consumptive crops. In this sense it is not incorrect to say that CAP policy measures support water demanding crops.

5.1.3.- *Social impact*

The agricultural demand for labour begins in all scenarios at almost identical values. In the water price interval from zero to ten Euro cents per cubic meter, although there is some variation, the changes are not especially significant in the aggregated demand for labour. In fact, the volume of agricultural labour in most scenarios is not greatly affected at the exception of the Agenda 2000 policy scenario.

Figure 11.15. Aggregated agricultural labour demand curve for Baixo Alentejo under different agricultural policy scenarios



5.1.4.- *Environmental impact*

The environmental impact of applying the WFD, as far as N applications are concerned, is quite positive in the agricultural markets liberalization, especially up to four Euro cents per cubic meter of water. In the Provincial Enterprise scenario the nitrogen inputs are hardly affected, ranging from 120 Kg/ha to around 90 Kg/ha at the end of the simulation. In other scenarios the nitrogen fertilizations are indeed influenced by water prices above 0.15 €/m^3. The pesticide indicator, based on the LD_{50}, tends to be progressively decreased as the water price rises. The exceptions are the reduction that occurs in the Agenda 2000 scenario for water prices near the 0.15 €/m^3 and the case of the pesticide risk in the Local Stewardship scenario which is not much affected for water prices below 0.33 €/m^3.

5.2. Lezíria do Tejo – Agricultural policy scenarios

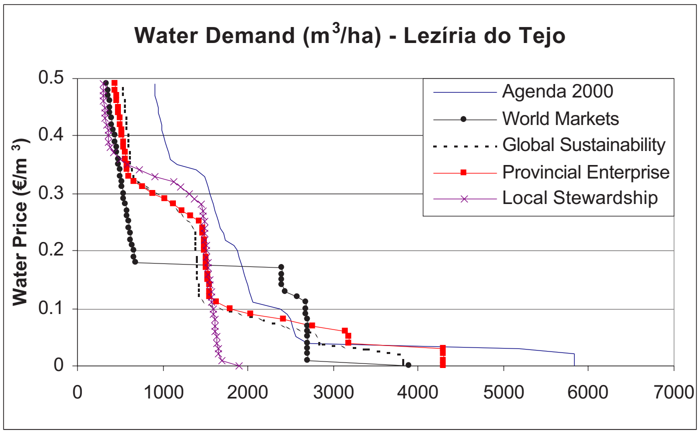
5.2.1.- *Water demand (m^3/ha)*

The aggregated water demand functions of the Lezíria do Tejo region for future policy scenarios are always on the left side, of the Agenda 2000 situation. On the one hand this is justified by the set of activities chosen to integrate each scenario at each water price, and on the other hand is due to higher irrigation efficiencies in these scenarios (a presupposed condition of these scenarios).

It is worth mentioning that the water demand functions in this region alternate elastic with inelastic segments that correspond to the change of crop patterns to less consumptive crops or rain fed crops. It is during the first elastic segment that volumetric water-pricing policies are expected to be more promising, as it is in these elastic segments that the responsiveness to pricing is higher (and with fewer side effects such as income loss and reduction of employment).

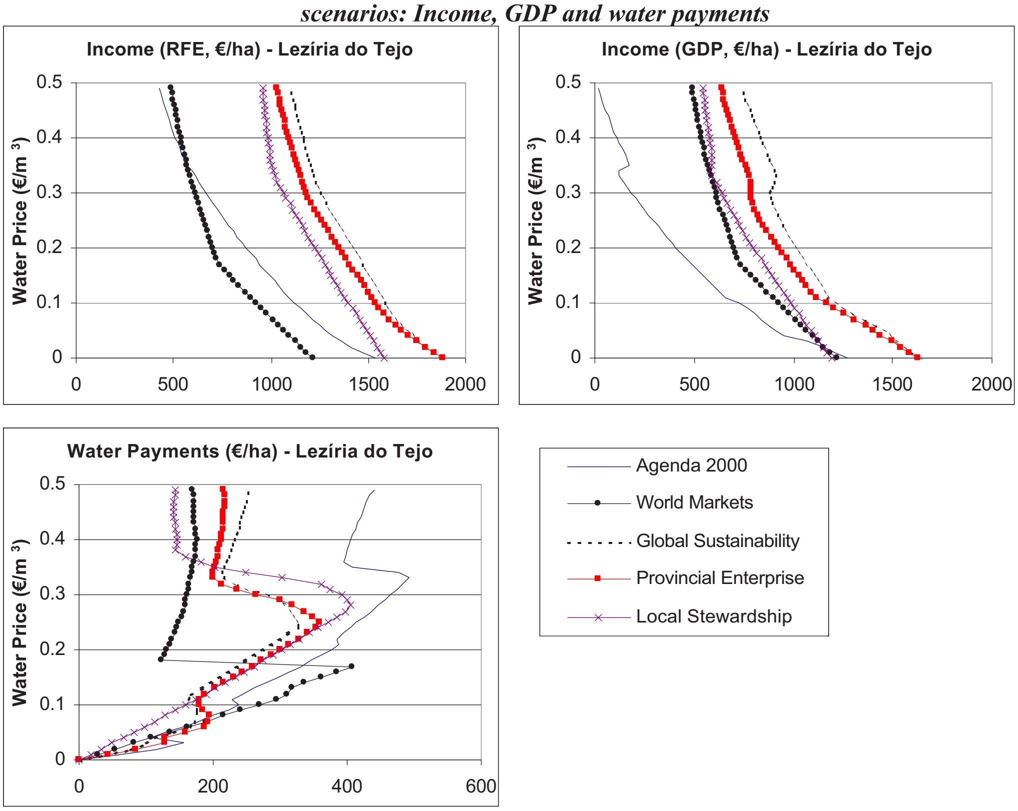
The water demand under the Local Stewardship scenario is much lower then in the other scenarios and seems to be quite resistant to water pricing fluctuations. Water savings are only expected to occur for water prices above 0.28 €/m^3. Lower water prices do not provide the necessary stimulus to induce a water reduction response.

Figure 11.16. Aggregated water demand curve for Lezíria do Tejo under different agricultural policy scenarios



5.2.2.- *Economic balance*

Figure 11.17. Aggregated economic results in Lezíria do Tejo under different agricultural policy scenarios: Income, GDP and water payments



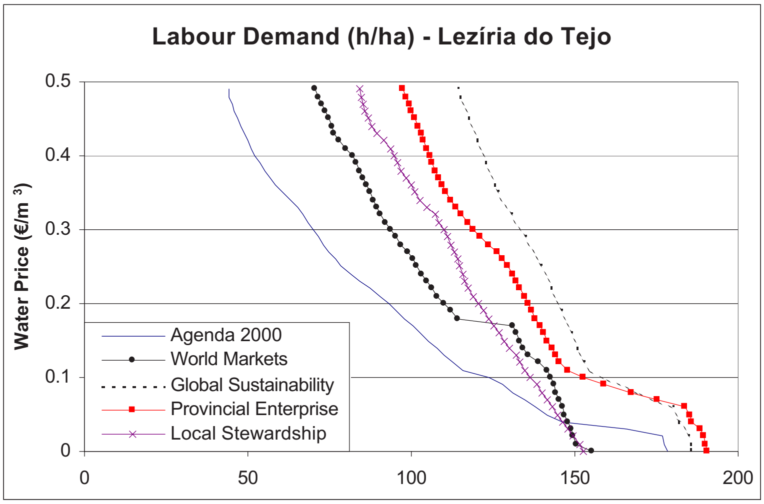
As in the previous region, for Lezíria do Tejo the Agenda 2000 is also the worst scenario, only surpassed by the World Market scenario at water prices below 0.36 €/m^3. Nevertheless, the level of farm income is much higher in Lezíria do Tejo.

Although the farm income curves reveal the same general tendencies, it is noticeable that subsidies vary greatly among scenarios. With the exception of the World Markets and Local Stewardship scenarios, the allocation of public funds increases by almost 150 €/ha during the first 0.10 €/m^3 increase in water prices. In the specific case of the Local Stewardship scenario, public support is always quite high and is almost unaffected by water pricing.

5.2.3.- *Social impact*

As far as the social implication of implementing the WFD is concerned, model results indicate that the amount of agricultural labour is most diminished in the Agenda 2000 policy scenario. In fact, during the first five Euro cents per cubic meter of water, the average reduction per each cent is of minus 7.4 h/ha, while the average value for future scenarios is minus1.3 h/ha in the same interval. The demand for labour is even more severely reduced in the water price interval between 0.05 €/m^3 and 0.1 €/m^3 in the Agenda 2000 scenario, with an average reduction (per cent of water price) of 3.6 h/ha against the 3.3 h/ha of future scenarios. The Local Stewardship scenario with lower initial demands for labour is able to resist better to water price increase.

Figure 11.18. Aggregated agricultural labour demand curves for Lezíria do Tejo under different agricultural policy scenarios



5.2.4.- *Environmental impact*

The assessment of the environmental consequences of policy change indicates the existence of contradictory results, depending on the indicator analysed. In the case of nitrogen fertilizations in most scenarios (with the exception of World Markets) there is no practical change in the amount of N inputs until water prices of 0.30 €/m^3. In the World Markets scenario there is a strong reduction of N fertilizations at a water price of 0.18 €/m^3 from more then 80 Kg/ha to less then 20 Kg/ha.

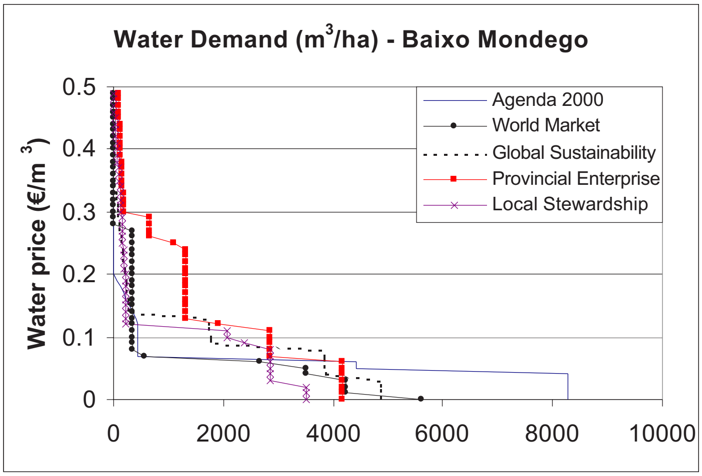
The pesticide risk indicator shows that water prices near 0.10 €/m^3 lead to very positive reductions of pesticide applications. In the case of the Local Stewardship scenario, severe reductions only occur at the water price of 0.30 €/m^3.

5.3. Baixo Mondego – Agricultural policy scenarios

5.3.1.- *Water demand (m³/ha)*

For water prices below six Euro cents per cubic meter, the demand for water for irrigation purposes is always lower in future scenarios then in the Agenda 2000 situation. This fact is explained by the large amount of surface dedicated to activities which consume a lot of water (such as rice and maize), and due to the irrigation efficiencies being significantly lower in the Agenda 2000 scenario (short term vs. long term modelling; future scenario considers the use of more efficient technologies). As this scenario represents the highest values of water demand, it is also the one where the demand more rapidly decreases with water pricing.

Figure 11.19. Aggregated water demand curve for Baixo Mondego under different agricultural policy scenarios



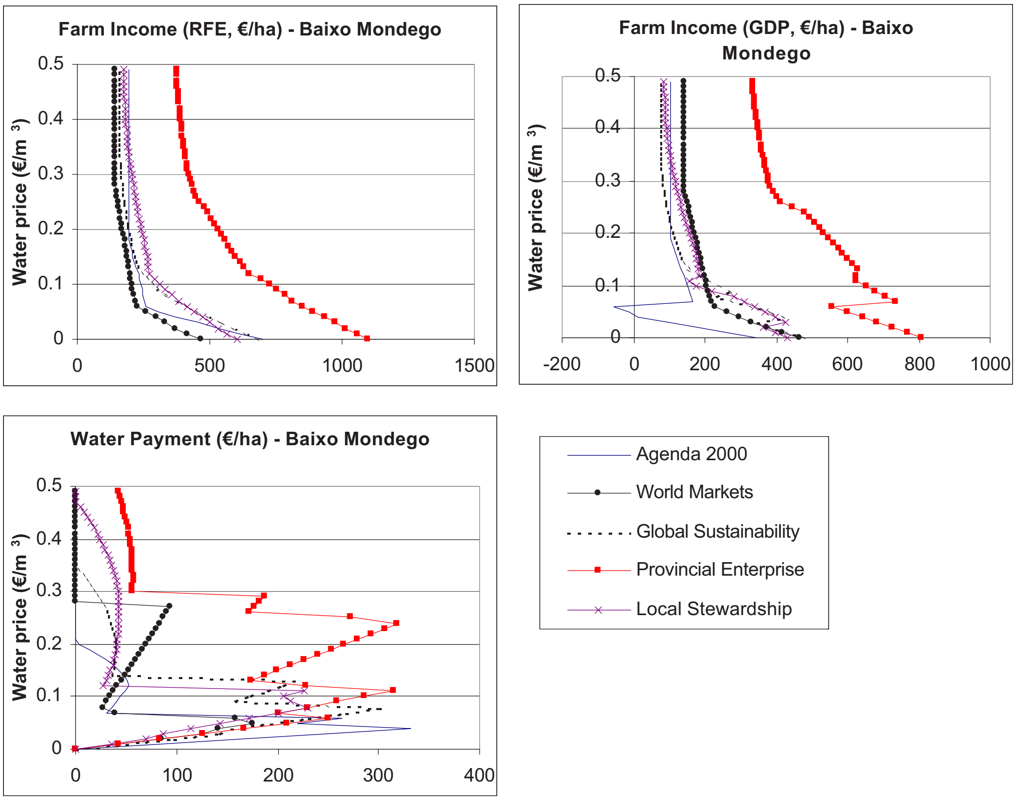
In general, it is possible to note that the capacity of resistance in Baixo Mondego to water price increases is very limited. In fact, for water prices above 0.13 €/m³, the agricultural demand for water is reduced to negligible values. With a water price of 0.05 €/m³ it is possible to note that the water savings in the Agenda 2000 and World Markets scenarios are estimated to range between 46.8% and 37.4% in comparison with a null water price situation; and that they are much lower in the Provincial Enterprise and Local Stewardship scenarios with 0.0% and 18.0%, respectively. Setting the water price at 0.10 €/m³ would led to the reduction of about 95% of the demand in the Agenda 2000 and World Markets scenarios, and of 31.3% and 41.2% in the Provincial Enterprise and Local Stewardship scenarios. Global Sustainability behaviour is in between previous scenarios. Is it also worthwhile mentioning that the Provincial Enterprise possibility is, in comparison, less responsive to the water price increase than in other scenarios.

5.3.2.- *Economic dalance*

The farm income in the majority of the scenarios is very similar, ranging from 700€/ha to 200€/ha. As mentioned above, the lack of responsiveness of the Provincial Enterprise scenario to water pricing is also reflected in a higher farm income. In fact, farm income curves follow the same general trends as water demand. Generally, the most significant income losses are registered up to ten Euro cents per cubic meter of water, although they are far more concentrated in the first 0.05 €/m^3. With the exception of the Provincial Enterprise scenario, the farm income reductions are, on average, calculated at 40% at a water price of 0.05 €/m^3 and 57% at the 0.10 €/m^3.

As the water price increases, there is a noticeable tendency for public funds allocation to agriculture to decrease. As traditional irrigated crops in this region capture public funds, the fact of being set aside from crop mix choices reduces the amount of direct payments. The public funds contributions to farm income do not usually register a very substantial decrease.

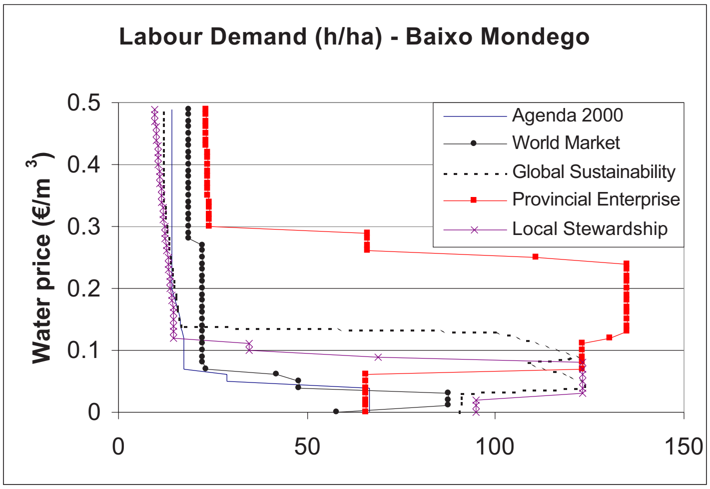
Figure 11.20. Aggregated economic results in Baixo Mondego under different agricultural policy scenarios: Income, GDP and water payments



5.3.3.- *Social impact*

The social implications of applying the WFD in this region are contradictory. If conditions are right to develop the animal sector and by this action promote the use of irrigated forage activities, the social impact seams to be positive. Extreme scenarios such as agricultural market liberalization ones, indicate that the demand for agricultural labour is likely to suffer reductions. This very same tendency is suggested by the water price increase in the current policy scenario.

Figure 11.21. Aggregated agricultural labour demand curves for Baixo Mondego under different agricultural policy scenarios



5.3.4.- *Environmental impact*

The environmental impacts of implementing a water pricing policy are not always very clear. In the presence of some scenarios, the case of Local Stewardship for instance, N inputs and pesticide risk are severely diminished, and in others, such as the Provincial Enterprise and World Markets, they are only slightly reduced.

6. CONCLUSIONS AND RECOMMENDATIONS

This study estimates the provisional impact that the Water Framework Directive (WFD) may have on three irrigated areas of Portugal (Baixo Alentejo, Lezíria do Tejo and Baixo Mondego). Instead of using general national or regional data, this project is locally developed for different types of agriculture and attends to farmers' different relevant criteria for decision-making using multi-criteria decision making models. After this process, the results are aggregated to reflect regional tendencies.

The implementation of a volumetric water tariff, such as the one studied, would appear to have a wide variety of consequences, especially concerning the reduction of the water demand for irrigation and the mitigation of environmental consequences of nitrogen fertilizations and pesticide use. Although results should always be interpreted locally, it is possible to say that the final impact, at the farm level, on the variables under analysis (income, water consumption, labour) depends as much on the scenario being considered as on the water price level. For instance, Global Sustainability impact on farm incomes would be the most advantageous for regions producing vegetables, while Provincial Enterprise and Local Stewardship would stimulate farm income in cereal based agricultures.

Often, for most of the variables under study, only the free-trade liberalization scenario provides worse results than in the Agenda 2000 situation. If, on the one hand, it is certain that these results are constrained by scenario assumptions, on the other hand it is possible to anticipate that future agricultural policies may promote better living standards in rural areas.

In general, the water price increase leads to the loss of farmers' well-being and to the loss of farm income, and, often, reduces the demand for agricultural labour. Depending on the water price selected to reflect the WFD principles, the necessary price increase may bring severe social problems within the agricultural sector and cause further employment asymmetries. Water price increases are manifested in different ways, but it is safe to say that they always imply the reduction of farm incomes, and it is important to highlight that they do not always imply increases in water agencies receipts.

In economic terms, the summation of the farm income with the amounts spent on water consumption are always lower then the farm income at free water levels which means that there is a loss of receipts. To add to this loss of benefits, one should consider the diminishment in agricultural areas of a fixed population. This is eventually the biggest problem that this environmentally sustainable promoting policy may imply in the fields of social and economic sustainability.

On environmental grounds, the reduction in water demand, and its best allocation among alternative activities that this policy measure aims to reach need to be highlighted. Secondly, in variable degrees and depending on the typology considered, the water price increase leads to the use of lower levels of inputs such as nitrogen fertilisers and pesticides, therefore with less environmentally damaging potential.

For each particular objective, there is one unique policy instrument that best serves that purpose. Therefore, priorities and preferential objectives for what is intended to be sustained should be made, considering economic, social and environmental aspects. That is, if the objective is to protect water bodies against excessive use, a regulation instrument such as a quota policy will probably be best suited; if the priority is to promote a rational and efficient use of water, the best policies to implement would be tradable rights or volumetric pricing policies; 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 (Saraiva and Pinheiro, 2003).

Considering that the effects of the WFD implementation depend as much on the agricultural policy scenario in force, and given the necessity of further integrating environmental aspects into the Common Agricultural Policy (CAP), the adoption of a water supply regulation (on a quota basis), constraining farm-level water use, could be used in association with the cross-compliance measures. Therefore, it could be advantageous to direct further studies to the use of regulating quotas associated with the use of cross compliance CAP policy measures.

Taking another approach, some improvements might be made by partially detaching concerns of water use efficiency from the farm level to that of water user associations and public irrigation schemes. Some examples to integrate in this research field would be, for instances, water requests, deliveries and time taken between these operations, flow monitoring and regulation, pressurised water flow, on-time flow interruption, property rights and possibilities of exploring water markets.

Considering all that has been said, it is very necessary to find a compromise solution, from a 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 and rural development in this regional/local context where agriculture is often the unique economic activity propelling development. It is also important to bear in mind that each region is a case with its particular peculiarities, so policy generalization may cause irreversible damage in one region despite being the best policy for a different region.

12.

Summary and conclusions

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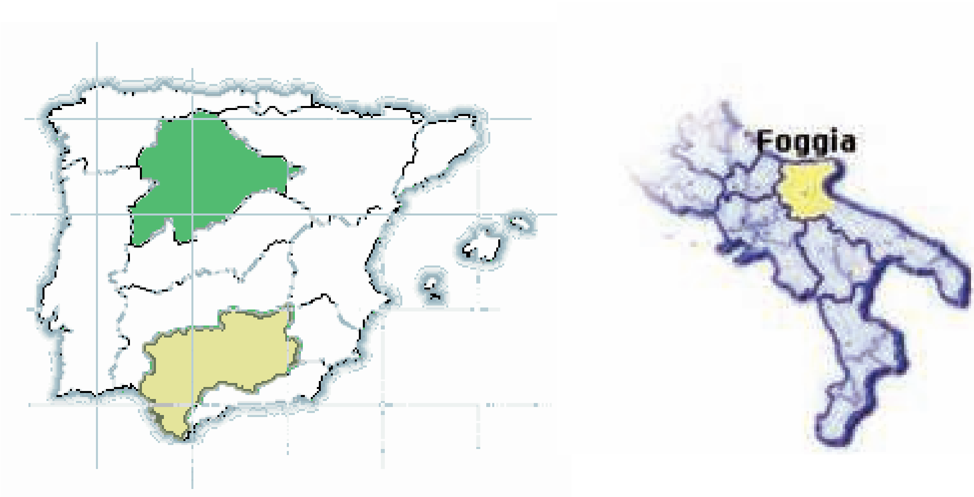
1. Main Results Of WADI Project

From the methodological point of view, our results are satisfactory, as the model has functioned fairly well in several countries and environments, as we have seen in Part II of this volume. At this point, however, we wish to highlight our empirical results, noting the following general conclusions:

- The scenarios turned out to be consistent
- A wide range of different farming systems were identified
- The methodology was robust and flexible
- A common European approach is possible.

These conclusions may be illustrated by means of some examples taken from the results illustrated in detail elsewhere in the report. Even between farming systems that may be considered similar, such as the Spanish and Italian, there may be remarkable differences, as we illustrate here with an example taken from chapters 6, 7 and 9, located in the areas shown in figure 12.1.

Figure 12.1. Examples of regions analysed



As an example, figure 12.2 jointly represents the two Spanish cases and one of the case studies developed in Italy (Foggia, southern Italy). When we study the water demand curves for the examples selected, we found the following differences in the three regions (see table 12.1 below).

Figure 12.2. Water demand function in the Duero basin (Northern Spain), Guadalquivir basin (Southern Spain) and Foggia (Southern Italy).

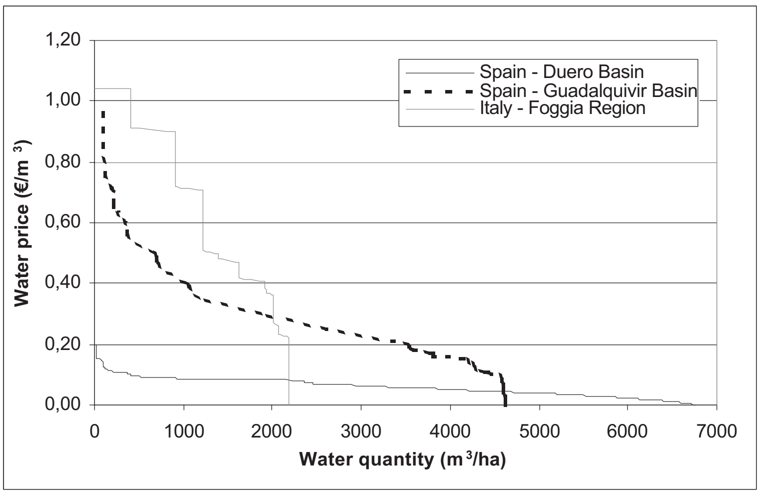


Table 12.1: Water demand characteristics.

Duero	Guadalquivir	Foggia
Demand disappears at 15 cents	Demand varies from 0 to 1€	Demand varies from 0 to 1 €
Elastic demand	Inelastic up to 10 cents. Then, elastic	Inelastic up to 23 cents. Then, elastic
High response to water price	Low response to water price	Low response to water price

An explanation of the curves belonging to the Spanish and Italian case can be found in the relevant chapters, and the above-mentioned three areas illustrate the need for detailed local analysis of policy impacts. Differences are even greater when we take into consideration cultivation systems in different countries, as the UK cases show (see chapter 10)

The Italian case, which was based on vegetable cultivation, shows a much lower level of water consumption and a much more rigid behaviour of the demand curve due to the high profitability of the crops cultivated. It is clear that water pricing policy would have completely different effects in these three contexts. Furthermore, in the Italian case increasing the price of water would have almost no effect in terms of diminishing water use

The case of irrigation in the UK is even more remarkable, as the areas involved are very small compared to Mediterranean countries but marginal water productivity is very high, reaching as much as 1.5 €/m^3 for high-quality vegetables (potatoes, etc.).

These differences in water productivity and demand will lead to differences in the responses to policy changes measured in terms of the selected sustainability indicators.

2. General Conclusions For Irrigation And WFD Implementation.

This report specifically analyses the possible evolution of some indicators for agriculture (socio-economic and environmental) as consequence of changes in European policy. We tested the present ‘business as usual’ or ‘status quo’ scenario against some alternative scenarios (some of the direction of CAP reform and WFD implementation) that were consistent with both the Water Policy Directive and CAP. The alternative scenarios are defined according to the WFD; a higher water price and CAP scenarios imply a decrease in pesticides, an increase in labour costs and a reduction in public-sector support via direct subsidies and via price reductions.

A general conclusion that applies to all countries is that the outcome forecast for 2010 is a movement in the direction of more sustainable agriculture with improvements in environmental indicators: lower water consumption, pesticide and nitrogen use and increasing soil cover. Set-aside will decrease under the ‘status quo’ scenario but will be maintained under the alternative scenario of global sustainability. There is also a synergetic effect in the improvement of environmental indicators. A reduction in pesticide and fertilizer use with a simultaneous decrease in water use will have a significant impact on water quality.

The results of the study under these alternative scenarios would produce quite different agricultural landscapes and the impact would differ according to the type of farmer and region being analysed.

We thus conclude that scenario analysis should be applied whenever possible to homogeneous farm types since the adaptation of farmers to changing environment depends upon technical and human resources and farmers’ objectives and values. There are two sources of variation: subjective, i.e. criteria for decision, and objective, i.e. technical equations and constraint levels.

As general conclusions relevant to European Policy Making, we may summarise some features of our results that are common to all irrigation systems in Europe:

> Result 1: Different but interlinked effects of policy instruments: agriculture (CAP) *vs.* environment (WFD) in the behaviour of agricultural systems.

Consequence: Need to integrate and co-ordinate the use of both instruments.

Result 2: Differences in behaviour of local farming systems with respect to water policy/agricultural scenarios.

Consequence: Need for detailed local analysis, taking into account water costs, the value of local agricultural products, policy design options, local institutions.

Result 3: Differences between 'socially driven irrigation' and 'commercial systems'.

Consequence: 'Social irrigation' is the basis of rural development, and water pricing will have negative social consequences. Crops depend upon CAP support. 'Commercial irrigation' is an economically valid use of water. Irrigation can accommodate full cost recovery. Crops are not dependent on CAP.

Result 4: In most of the regions the number of irrigated crops available is very limited. In most Mediterranean areas alternative rain-fed crops do not guarantee adequate profitability.

Consequence: Some irrigated systems are quite fragile and support for them may be necessary if their viability is socially desirable.

3. WFD Implementation And Economics

According to Lionel Robbins, economics is the science of scarce resources available for competing uses, and it is difficult to find a natural resource which this definition fits better than water. Water can be used for agriculture, industry, urban services or environmental functions, and arid regions have a potentially higher demand than natural resources can supply. Even in agriculture, some territorial conflicts may occur when farming systems compete for water (e.g. the current national hydrological debate in Spain).

As a conclusion to this working paper, we would like to point out that water management and policy decisions should be supported by sound economic analysis. Such a conclusion can be drawn from the implementation of the WFD, where social science disciplines are particularly needed in order to

- Understand **the value and cost of water**, and the multiple links between uses, consumption, pollution (with impacts in terms of overall economic output, trade and employment)
- Assess the **cost and benefits of proposed programmes of measures** aimed at improving water status, and in this way detect the need to develop accompanying measures to facilitate the implementation of proposed measures and limit their negative impact
- **Support the development of economic and financial instruments** (e.g. water prices, pollution charges or environmental taxes), that could be effective as a means of attaining environmental objectives
- Propose **institutional measures** to facilitate the achievement of objectives (e.g. markets, quotas, economic support).

All these items should be dealt with as soon as possible, as we are behind schedule on the implementation timetable, and there is a real need to improve water use in Europe, which should not be delayed further. However, this research agenda is subject to the following constraints:

- Lack of economic expertise in many government agencies; most European basin authorities have focused on supply enlargement and quality control and most of their personnel come from civil engineering or environmental sciences.
- Lack of expertise in countries (consultants, researchers) where there is little tradition of this type of analysis.
- Complexities and difficulties in assessing the financial cost of water services where territorial and sectorial problems are present and the proper definition of water use, consumption and quality is a difficult task.
- Inadequate integration between economics and other disciplines, mainly ecology, and hydrogeological interactions with economic models.

4. THE FUTURE OF AGRICULTURAL ECONOMICS MODELS

Future demands for agricultural economists and operational researchers also imply a demand for models capable of generating detailed microanalyses based upon diversity in farming systems. Such diversity appears to be greater than ever, as conventional agriculture faces up to organic farming, and as various technologies (GMOs, etc.) compete for consumer markets; global equilibrium may not reflect diversity in the adaptation of strategies and the impact of measures.

For this reason, we need to encourage the development and adoption of simple models of irrigated agriculture that are capable of simulating changing policy scenarios and measuring the impact of such changes on social, economic and environmental indicators. Farmers are not economic automatons; they make choices among different priorities, but our economic system will continue to be based upon freedom of choice exercised by individuals (farmers, consumers) and the role of policy-makers will be to achieve compromises between conflicting social and environmental goals without affecting the economic, social and environmental sustainability of rural life. We believe that WADI has contributed to this process by suggesting suitable tools for this purpose.

Where irrigation analysis is concerned, it is essential for the successful implementation of the WFD to provide some answers to the four points recalled above.

Agricultural economic models may help us to understand **the value and cost of water** and the multiple links between uses, consumption and pollution, by simulating the way in which these aspects are connected through the farming systems and their adaptation to external scenarios.

Researchers may contribute to the evaluation of the **cost and benefits of the proposed programme of measures**, through the simulation of farms and system reaction both in a static and a dynamic framework, taking into account personal objectives and socio-economic characteristics of farms.

Economists should **support the development of economic and financial instruments** (e.g. water pricing, pollution charges or environmental taxes), that may be effective as means of attaining environmental objectives, through the use of suitable policy design models.

Finally, modelling can support the definition of **institutional measures** that will facilitate the achievement of objectives (e.g. markets, quotas, economic support), by identifying incentive- and institutionally compatible alternatives and supporting their choice through simulations of their results.

Models could play a major role in the analysis and management of conflict of water use as well as in the analysis of the potential benefits of cost-sharing.

Finally, with regard to the use of environmental, social and economic indicators, we believe that the integration of a set of indicators can contribute to evaluations of environmental impact of irrigated agriculture and our selection of 'means-based' indicators have proved to be simple but powerful means of helping decision makers at various levels (community, regional, national, global).

The modelling approach developed during WADI could be extended to a wider range of problems than irrigated agriculture itself, possibly to all policy and market changes that are likely to have an effect on the farming system.

Nevertheless, the contribution of models to decision-making requires, as a necessary preliminary step, a better definition of agricultural strategy. The EU could better clarify its objectives in terms of agricultural policy in order to achieve better co-ordination with water policy; the general public and farm managers are still poorly informed about agriculture as well as about economics.

Secondly, the set of politically feasible policy instruments should be better defined. Within those instruments, modelling support could contribute by carrying out more detailed policy simulations and analyses, using the most suitable approach.

5. CONCLUDING REMARKS

This report summarises several years of European research in the fields of agricultural economics and decision theory applied to the irrigated agriculture throughout a Europe that is at a crossroads from a normative viewpoint.

The consortium has developed a European network, and we may say that our methodology for the analysis of farming system is well adapted to European agriculture because the complexities of our agriculture is better captured by multicriteria models of farmers' behaviour. On the contrary, other OECD farming systems (e.g. North American) are more commercially oriented, and profit maximizing is a reasonable assumption for their behaviour against the more complex behaviour involved in European farming.

We are reasonably satisfied with the global results obtained by the methodological implementation of multicriteria models, as similar methods have been applied to a range of European agricultural systems, offering sound results that are an improvement on those obtained by single-criteria models. The integration of indicators into multicriteria models was also successful, clarifying the use of scenarios.

We hope that this book has managed to illustrate the main points of our research and thus to support agricultural economists in their profession and European society to make a wise implementation of WFD and CAP normative.

13.

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