# The regional impact of irrigation water pricing in Greece under alternative scenarios of European policy: a multicriteria analysis

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# The regional impact of irrigation water pricing in Greece under alternative scenarios of European policy: a multicriteria analysis


## ABSTRACT

This study simulates the impact that various policies based upon the water price have on agricultural production and analyzes the economic, social and environmental implications of alternative irrigation water policies using a multicriteria model. For the purpose of scenario analysis, narratives and quantitative indicator values have been compiled. The results show that the increase of water price causes almost similar impacts with those that were observed in the status quo scenario. The results also stress that water pricing as a single instrument for controlling irrigation water use is not a satisfactory tool for significantly reducing water consumption in agriculture.



**Keywords:** Irrigated agriculture, Water price, Scenario analysis, Multicriteria model, Utility optimization, Economic, social and environmental impacts

**JEL Classifications:** Q0, Q1, Q2, G13


## INTRODUCTION

European irrigated agriculture is very important in terms of area, value of production and employment, especially in certain Mediterranean regions devoted to continental agriculture. The management and use of water and water resources have been the focus of EU water policy since the 1960s. The Water Framework Directive 2000/60/EC (WFD) established a structure of community action in the field of water policy. Several possibilities for water policy have been debated, in particular for the pricing of irrigation water. The discussion is related to the potential savings that might come along with charging additional water fees. This study, elaborated in the context of the European research project "European Irrigated Agriculture under Water Framework Directive-WADI" (BERBEL *et al.,* 2002), contributes to that discussion by simulating the impact that various policies based upon the price of water could have on agricultural production.

The analysis of the effects of water pricing on irrigated agriculture and farms behavior ought to be an important topic of research for European agricultural and environmental economists (ARRIAZA *et al.,* 2002; BERBEL and GOMEZ-LIMON, 2000; GOMEZ-LIMON *et al.*, 2002; GOMEZ-LIMON and BERBEL, 1995). Following this observation, this paper aims to analyze the regional impact of irrigation water pricing under the alternative scenarios of European water policy. Specifically, the study analyzes the economic, social and environmental implications of alternative irrigation water policies using a multicriteria model of farmers' behavior under different scenarios.

The future agricultural and water scenarios are based on a global and national review of future scenarios developed by the UK foresight program (BERKHOUT *et al.,* 1998; DTI, 1999, 2002) in which water policy reflects a mix of governmental and social preference. The scenarios are further described in terms of the combination of policy instruments, policy style and configuration of actors. The links between the foresight type scenarios and the scenarios for European agriculture, together with a brief description of the agricultural policy regime are shown in Table 1.

The methodology, based on Multicriteria Decision Making (MCDM) theory (ROMERO and REHMAN, 1989; REHMAN and ROMERO, 1993) will be implemented in a real irrigation system, enabling us to build a model to analyze how the recent CAP reform has influenced the water demand function and how hypothetical new reforms would affect the irrigation unit studied.

Specifically, we used an MCDM model in order to achieve better policy-making procedures and the simulation of the most realistic decision process. The MCDM model was chosen because of the variety of criteria taken into account by farmers when they plan their crop plans broadening in this way the traditional assumption of profit maximization. It also assembles the multifuntionality of irrigated agriculture involving variables related with economic, social and environmental aspects. The used MCDM model is actually a utility maximization model with multiple criteria**.**

The utility MCDM approaches in comparison with other approaches as Linear Programming, Cost-Benefit analysis etc. can achieve optimum farm resource allocations (land, labor, capital, water etc.) that imply the simultaneous optimization of several conflicting criteria, such as the maximization of gross margin, the minimization of risk, the minimization of labor used etc. However, although utility optimization is the core of the analysis in this study, the used MCDM model does not comply with others schools in MCDA like 'Social MCDM' which include extensive stakeholder participation and seekcompromise solutions.

Both SUMPSI *et al*. (1997) and AMADOR *et al*. (1998) have developed methodologies for the analysis and simulation of agricultural systems based on multi-criteria techniques applied to irrigated agriculture. This methodology has been successfully implemented on real agricultural systems (BERBEL and RODRIGUGEZ, 1998; GOMEZ-LIMON and BERBEL, 1995). BERBEL and GOMEZ-LIMON (2000); ARRIAZA, GOMEZ-LIMON and UPTON (2002); GOMEZ-LIMON *et al*. (2002); ZEKRI and ROMERO (1993) have applied this methodology to analyze the local irrigation water market in Spain.

## CONSTRUCTION OF FUTURE SCENARIOS

For the purpose of scenario analysis, narratives and quantitative indicator values have been compiled for each scenario. The quantitative estimates are used as input values in the modeling of irrigation systems under policy changes.

The future agricultural and water scenarios are constructed on a global and national review of future scenarios developed by the UK foresight program (DTI, 1999, 2002) as they were specialized in WADI project (BERBEL et al., 2002; MORRIS and VASILEIOU, 2003). Scenarios are not intended to predict the future 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 reform present decisions.
- there are many possible futures: scenarios map a ‘possibility space’.
- scenario development involves a mix of rational analysis and subjective judgment.

Thus, scenarios are statements of what is possible; of prospective rather than predictive futures; propositions of what could be. They are often made up of a qualitative storyline and a set of quantitative indicators, which describe a possible future outcome. Scenarios arise as a consequence of modeling drivers of economic and social change, new trends and innovation, and of unexpected events.

The baseline is the agricultural policy regime in 2003 (status quo), as determined by CAP at that time, which is used to provide a relative reference point for the definition of future scenarios. The baseline will also be extrapolated to 2010 based on predictions of agricultural markets and prices from EU, OECD and other sources. This extrapolated baseline is perceived to be different from the possible futures identified in Table 1, although it shows a tendency, due to predicted reform of CAP and greater influence of WFD, towards global sustainable agriculture.

The foresight program has constructed four possible futures that are distinguished in terms of social values and governance.

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

**Global Sustainability** is characterized 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 characterized 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 at work only within the national/regional boundaries. Provincial agricultural markets are also characterized by protectionist regimes similar to that under pre-reform CAP.

**Local Stewardship** is characterized by strong local or regional governments, which emphasize social values, encouraging self-reliance, self-sufficiency, and conservation of natural resources and the environment. Local community agriculture, as the label implies, emphasizes sustainability at a local level.

These broad generic scenarios define the possible future scenarios in which sectors such as agriculture, and sub-sectors such as irrigated agriculture, would operate if the particular futures are realized.

## AREA OF STUDY

Greece has arid climate that makes irrigated agriculture more productive than dry-land agriculture. Thus irrigation is one of the principal users of water. To analyze the consequences of the application of alternative pricing policies for irrigation water, we selected an irrigated area belonging to the prefecture of Xanthi in Northeastern Greece. The reason behind selecting this particular area is that it is a good representative irrigated area of North and Eastern Greece with high water consumption crops such as corn, cotton and tobacco as well as non-irrigated crops such as wheat, barley and hard wheat and is fairly homogeneous both in physical terms (soil and climate) and socio-economic conditions. Most irrigation in the concerned area is applied by sprinklers and is based on pressure. The climate is the usual Mediterranean one with special characteristic of dryness during the summer. The agricultural land is constituted by a combination of fertile and poor soils and the dominant system for all types of crops works to support irrigation from late spring to early autumn.

## DATA

The necessary data which refer to the period of 1995-2001, were gathered from the villages and municipalities that are located in the region, the prefectures of Xanthi, the Ministry of Agriculture, the Statistical Service of Greece, the regional government of East Macedonia and Thrace, etc. The technical and economic coefficients of crops were collected from 25 farms belonging to the irrigation region of Xanthi using a questionnaire (Table 2). We also used additional data that were provided by the Department of Agricultural Economics of Aristotle University of Thessaloniki in Greece.

In this study the possible prices for agricultural inputs and outputs under the alternative agricultural policy scenarios by 2010 are expressed as a % of the existing year 2001 at fixed values (Table 3).

*Crops*

Cereals and industrial crops represent the largest proportion of irrigated production in the region selected for study. They can represent good indicators of the short-term behavior of farmers when water policy is being changed. We also included alfalfa because of its significant share of land utilization in the study area.

As it is known, the European "Common Agricultural Policy" (CAP) obliges farmers devoted to growing cereals and corn to set aside land if they wish to receive subsidies for agricultural production.

*Yields*

In order to give the system as much freedom as possible regarding land use and water allocation, each activity (crop) was allocated to a range of different intensities of water usage (deficit watering), giving farmers the opportunity to choose between different levels of water supply.

*Prices*

Prices applied to crops are averages for the study region obtained from the official statistics of the regional authorities. We used historical time series data for the 7-year period 1995-2001, after the prices have been adjusted for inflation (2001).

*Subsidies*

Subsidies depend upon the European Union's CAP, and were obtained from official publications of the regional authorities.

*Income*

Income is an important attribute of the system as it defines total agricultural output. Income was computed by the simple combination of yields and prices, plus subsidies where applicable.

*Variable costs*

We took into account six categories of variable costs in order to describe the inputs: (i) seeds, (ii) fertilizers, (iii) chemicals, (iv) machinery, (v) labor, and (vi) cost of water. Especially, the cost of water includes the cost paid to the regional organization of irrigation networks, the electricity/fuel cost of pumping and the simulated price of water (to be parameterized from zero to 0.15 €/$m^3$).

*Gross margin*

Gross margin can be computed using the data regarding prices, yields, subsidies and variable costs. It was calculated from the total income minus total variable costs. We used this parameter as the best estimator of profit and thus the function of the total gross margin of the production plan could be considered as an objective for the model.

To run the MCDM model, we need similar units for all inputs. For this reason we transferred all the inputs into cost (Euro/ha) instead of keeping them in their initial natural units such as kg, number, area, cubic cm, etc. The inputs were transferred to costs by multiplying each input used by the corresponding per unit input price.

*Other attributes*

We estimated the fertilizer use even if it was not a relevant attribute for farmers, since they considered it as a cost and not as a decision variable. Nevertheless, this criterion was relevant for policy analysis, as it might represent the environmental impact (non-point pollution caused by nitrogen fertilization). There was also a detailed analysis of water demand and labor use, since both attributes were included in the MCDM model in the objectives part (labor use) and in the constraints part (water demand). Thus, the values of these variables would be known as outcomes of the system and would be used later in policy analysis.

## THE UTILITY FUNCTION

In the present study, we used utility functions where the ability to simulate real decision-makers' preferences is based on the estimation of relative weightings. These utility functions are a good approximation to the farmers' hypothetical utility functions.

The relative methodology was developed by SUMPSI *et a1.* (1993, 1997) and extended by AMADOR *et α1.* (1998). It is based upon Weighted Goal Programming and has previously been used by BERBEL and RODRIGUEZ (1998); GOMEZ-LIMON and ARRIAZA (2000); GOMEZ-LIMON and BERBEL (2000). With this methodology a surrogate utility function is estimated, which is used to estimate the water demand for crop production.

The following steps were followed:

1. Establishment of a set of objectives $f_1(x)...f_i(x)...f_n(x)$ that may be supposed to be the most important for farmers and represent the real objectives of the farmers (e.g. profit maximization, risk minimization).

2. Calculation of the pay-off matrix for the above objectives, which has the following formulation:

| Objective/ attributes | $f_1(x)$ | $f_2(x)$… | …$f_i(x)$… | …$f_q(x)$ |
|---|---|---|---|---|
| $f_1(x)$ | $f_1^*$ | $f_{12}$ | $f_{1i}$ | $f_{1q}$ |
| $f_2(x)$ | $f_{21}$ | $f_2^*$ | $f_{2i}$ | $f_{2q}$ |
| …$f_i(x)$ | $f_{i1}$ | $f_{i2}$ | $f_i^*$ | $f_{iq}$ |
| …$f_q(x)$ | $f_{q1}$ | $f_{q2}$ | $f_{qi}$ | $f_q^*$ |

(1)

The elements of the matrix need to be calculated by optimizing one objective in each row. Thus, $f_{ij}$ is the value of the *i-th* attribute when the *j*-th objective is optimized.

3. Estimation of a set of weights that optimally reflect farmers' preferences. Once the pay-off matrix has been obtained, the following system of $q$ (number of objectives) equations is solved:

$$\sum_{j=1}^{q} w_j f_{ij} = f_i \qquad i = 1, 2,...,q; \text{ and} \tag{2}$$

$$\sum_{j=1}^{q} w_j = 1$$

where, $q$ is the number of relevant objectives that was fixed previously, $w_j$ are the weights attached to each objective (the solution), $f_{ij}$ are the elements of the pay-off matrix and $f_i$ are the real values that show the observed behavior of farmers in the existing situation.

4. Since the above system does not result in a set of $w_j$ (weights of each objective that reproduce the actual behavior of the farmer), it is necessary to search for the best possible solution by minimizing the sum of deviational variables that finds the closer set of weights. For this purpose (ROMERO, 1991) the following model of Linear Programming (Model (3)) has been solved:

$$\text{Min} \sum_{i=1}^{q} \frac{n_i + p_i}{f_i} \tag{3}$$

subject to:

$$\sum_{j=1}^{q} w_j f_{ij} + n_i - p_i = f_i \text{ , } i = 1, 2, \ldots q$$

and $\sum_{j=1}^{q} w_j = 1$

where, $p_i$ is the positive deviational variable that measures the difference between real value and optimum solution for the $i$-th objective, and $n_i$ is the negative deviational variable.

## MODEL DEFINITION

*Decision variables*

Each farmer of the region has a set of variables $X_i$ (crops), such as: wheat, barley, corn, alfalfa, tobacco, cotton, sugar beets, tomatoes, hard wheat and set aside (no fruit trees) as described above and presented in Table 2. These are the decision variables that can assume any value belonging to the feasible set.

For each irrigated crop we considered two or three different levels of irrigation.

*Objectives*

We selected 3 objectives to be considered as belonging to the farmers' decision-making process.

*Maximization of gross margin:* Gross margin (GM) is a good estimator of profit. Thus the maximization of profit in the short-run is equivalent to the maximization of gross margin. The objective function included in the model is determined as below:

$$GM = \sum_{i=1}^{q} GM_i \times X_i \tag{4}$$

where, $X_i$ is the area of $i$-th crop in hectare (ha) and $GM_i$ is the gross margin of $i$-th crop in euro per ha.

*Minimization of risk:* The variations of prices and yields play a very important role in the agricultural production and risk is therefore always present in any agricultural system. The farmers have a remarkable aversion to the risk, something that should be included in the model. In this case the risk is measured as the variance of the total GM. Thus the risk is calculated by the type:

$$\text{Total risk} = \bar{x}_i^t \, [Cov] \, \bar{x}_i \tag{5}$$

where, [Cov] is the variance/covariance matrix of gross margins during the period of 7 years, and $X_i$ is the vector of areas of each crop in ha.

*Minimization of labor:* The minimization of labor implies not only a reduction of input cost, but also an increase of leisure time and reduction of administration and management processes. The farmers usually show an aversion to hiring labor. An explanation of this behavior is that this parameter is connected with the complexity of crops because the hired labor adds a degree of complexity to family farming. For this reason, labor is calculated as the sum of labor for all farm activities (TL), therefore the objective function will be:

$$\sum_{i=1}^{q} TL_i \times X_i = TL \qquad (6)$$

*Constraints*

*Total cultivation area:* The total area of all crops ($X_i$) should be equal to 100. This constraint is used in order to have the results of the model (decision variables $X_i$) in percentages.

*Common agricultural policy (CAP):* A large proportion of agricultural income depends upon CAP subsidies. For this reason, the farmers cannot avoid the CAP regulations that influence most of the crops available for cultivation. Following the CAP rules, we must include a variable for the set aside (SA) activity that is related to the subsidized crops

$$\sum_{i=1}^{q} X_i + SA = 100 \qquad (7)$$

SA must be at least the 10% of the land that is occupied by cereals and corn. Sugar beets, tobacco and cotton are also constrained to be less than the historical quota (period 1995-2001) plus 5% (for the new farmers).

*Market and other constraints:* Marketing channels and/or processing facilities put an upper limit on short-term variations of some crops. This is the case for alfalfa. We have fixed the upper limit for alfalfa on the basis of the maximum historical cultivation during the period 1995-2001 plus 20%.

*Rotational and agronomic considerations:* A rotational constraint limits the cultivated area for a crop to a maximum of 60% of the total available area, and applies to all crops except alfalfa. We also applied a constraint for all other crops that their historical quota is less than 10% of the total area. We consider that these crops can be cultivated to a maximum of 10% of the total available area.

All this information has been included in the model that forms the basis for the MCDM simulation.

*Attributes*

Attributes are useful indicators, which are deduced as functions of decision variables. From this viewpoint we have considered several attributes that are relevant to policy makers but that are not taken into consideration in the farmers' decision-making process. The analyzed attributes are:

*a. Water consumption:* The projected consumption of water measured in $m^3$/ha is the variable that policy makers wish to control as a consequence of changes in water management policy.

*b. Economic impact:* We measured the economic impact of changes in policy by measuring two variables: farm income and public support from water pricing, both measured in €/ha.

*c. Social impact:* Since irrigated agriculture is one of the main sources of employment in Greece, any change in policy will significantly affect the social structure of rural areas. This attribute is measured also by two variables: farm employment (man-days/ha) and seasonality (man-days/month).

*d. Environmental impact:* We used two variables to measure the environmental impact of irrigated agriculture: the demand for fertilizers measured in kilograms of nitrogen added per ha and the energy balance ($10^5$ kcal/ha).

*e. Landscape and biodiversity:* Finally, we used two variables in order to measure the impact of irrigated agriculture on landscape and biodiversity: the genetic diversity (number of crops of the farm plan) and soil covered by crops (months/year).

We included above the minimization of labor as an objective in MCDM model. At the time of analysis, when labor is minimized, labor cost item is dropped from the constraints of the model. Thus double counting effects of labor are avoided.

Moreover, the problem of double counting of water costs during the simulation procedure is overcome by adding only the extra cost of increased water prices to the initial variable cost for each crop. This increased variable cost is subtracted from the gross return to get the new gross margin. We run the MCDM model using the new gross margin in order to estimate the effect of water price changes on the economy, society and environment under different scenarios.

## MODEL APPLICATION

The application of the MCDM model includes four steps. In the first step, three objectives $f_i(x)$, $i$ = 1, 2, 3 were selected that were described above with their respective mathematical functions (maximum gross margin, minimum variance and minimum labor).

In the second step, the pay-off matrix was obtained by solving each time the Linear or Quadratic (when the variance is considered) Programming model using correspondingly the software LINDO or LINGO. The pay-off matrix for the study region is presented in Table 4. The values in the second, third and fourth columns of this table correspond to the values of objective functions $f_{ij}$ (see model 3). The last column shows the existing farm plan in the study region. These are the values of $f_i$ that show the actual crop distribution in the region (for 100 ha) and the relation among different crops and the objectives considered. Thus we can see how far the existing situation is from each separate optimum. This prompts us to try a combination of the three objectives for a better simulation of farmers' behavior.

In the third step, the set of weights was obtained that best reflects farmers' preferences and minimizes deviations from the present real values. More specifically, taking the above values *fi* and *fij* from the solution of model (3) the following weights were resulted: $W_1$ (maximization of gross margin) = 0.88, $W_2$ (minimization of risk) = 0.00 and $W_3$ (minimization of Labor) = 0.12. The calculation of these weights was based on the existing situation, where the water price was zero.

From these weights we may deduce that the farmers' utility function is

U=0.88 GM – 0.12 TL

This function shows that farmers in the region behave according to an additive utility function, in which the most important criterion appears to be the total gross margin and then the labor used.

In the fourth step, the estimated utility function was used as objective function of the MCDM model in order to obtain the optimum production plan for each scenario and the simulation procedure.

In the fourth step, each variable is multiplied by the above obtained weights. Thus, each time a new utility function was used as objective function of the MCDM model. The new utility function was maximized 9 times for each one scenario separately, in order to obtain the simulated optimum production plans in the study region.

## RESULTS AND DISCUSSION

### *Water use ($m^3$/ha) and crop plan*

The results show firstly the farmers' responses for water demand in relation to its price changes among alternative policy scenarios. Table 5 shows the changes in the crop plan in status quo scenario, as an adaptation to the rising cost of water resources; low water prices imply high water consumption crops, but as the price of water increases, irrigated crops are replaced by non-irrigated crops. The water price until 0.03 €/$m^3$ threshold is characterized by a relatively stable crop plan without significant difference in water demand. On the other hand, above this price threshold, the crop plans change, bringing about a large fall in the demand for water. Finally, from the price 0.11 €/$m^3$ the crop plan is characterized again by a relative stability without significant difference in water demand (Figure 1 and Table 5).

From the comparison among all future scenarios (Table 6), we can conclude that the crop plans are stable in all scenarios except the world market scenario. As we can see in Table 6, the area for cotton is replaced by hard wheat in world market scenario production plan, keeping all other crops stable in farmers' crop plan decisions.

We can also conclude that the increase of water prices reduces the water consumption in all future scenarios. The water demand curves for all scenarios are very similar except the world market scenario curve. World market scenario has the lowest demand for water until being supplanted by the status quo scenario at the 0.05 €/$m^3$ water price. In the water price 0.11 €/$m^3$ and above, the world market water consumption becomes lower than status quo scenario as well as than all other scenarios (Figure 1).

### *Economic impact*

As regards the impact of new water policies on the farm income, we observe that in the study region there is a reduction of farm income in all scenarios. Farmers respond to water price increases by reducing the water consumption through changes in production plans, introducing less profitable crops as substitutes to the more valuable water-intensive crops. These changes significantly decrease farmers' incomes. As a result of increasing water price from zero to 0.15 €/m$^3$ the farm income reduces by 15.0%, 15.6%, 17.3% and 11.3% in world market, global sustainability, provincial enterprise and local stewardship scenario respectively compared to 23.8% in status quo scenario (Figure 2).

In the local stewardship scenario, farm income is the lowest of all types of scenarios in each level of water price. Farm income is the highest for global sustainability followed by provincial enterprise scenario, status quo and world market scenario for all water prices (Figure 2).

On the other hand, in zero water price level, the world market and global sustainability had no remarkable effect on public support. The provincial enterprise and local stewardship had little effect on public support compared to other scenarios (Table 7).

*Social impact*

Pricing of water brings about a severe reduction in farm labor inputs in the short term as a result of responses to price increases by reducing water consumption through changes in crop plans, substituting higher-value/higher labor or water-intensive crops with less profitable crops. This implies that less water demanding or dry crops and more mechanized crops will replace water intensive crops, which will result in a continuous reduction of employment. This reduction reaches 12.0%, 8.7%, 9.5% and 8.2% in world market, global sustainability, provincial enterprise and local stewardship scenario, respectively; compared to 14.4% in status quo scenario in response of increased water prices from zero to 0.15 €/m$^3$. The result shows that except water price 0.03 €/m$^3$ in case of all prices farm employment is the lowest for world market compared to other scenarios. In zero water price level, farm employment remains the same (421.85 man-days/ha) in case of all scenarios except world market scenario (Figure 3).

In Table 7, it is depicted that seasonality was the lowest in world market and the highest in provincial enterprise and local stewardship scenarios. In case of global sustainability it was the same as status quo scenario.

*Environmental impact*

Figure 4 shows that water pricing leads to a significant reduction in fertilizer use as a result of modifications of crop plans and the introduction of less productive crops in case of all scenarios. Obviously, as farmers substitute crops in order to save water, fertilizer use directly decreases.

In zero water price, fertilizer use remains the same (647.14 kg/ha) in case of all scenarios except the world market scenario. As a result of increasing water price from zero to 0.15 €/m$^3$ the rate of reduction reaches the highest in world market (15.9%) and the lowest in local stewardship scenario (10.9%) (Figure 4). From the figure it is noticed that in water price level zero until 0.03 €/m$^3$ and from 0.13 €/m$^3$ and above, a smaller reduction in fertilizer use is observed in case of all scenarios. The rate of reduction is higher in all scenarios within the water price 0.05 to 0.11€/m$^3$.

It is very important to note that the energy balance was almost static for all types of scenarios including status quo scenario. This indicates that in case of each scenario there was no effect on energy balance in the region of Xanthi. The nitrogen balance is the highest for status quo scenario compared to other scenarios that are almost the same (Table 7).

*Landscape and biodiversity*

In the water price level zero €/m$^3$, landscape and biodiversity differ in different scenarios. The result suggested by the global sustainability is the highest in case of genetic diversity than other scenarios as well as status quo. Except the global sustainability, genetic diversity is the same for all types of scenarios. On the other hand, farmers followed almost the same cropping mix (soil cover) as status quo scenario, in world market and global sustainability scenarios. The soils were covered by 6 months both for provincial enterprise and local stewardship, which are smaller than status quo (Table 7).

The results obtained are consistent with other studies based on the estimation of water price elasticities conducted by different authors. The findings of the research by GOMEZ-LIMON and BERBEL (2000) concluded that the price of water would have to be increased to as much as 0.049

€/m$^3$ (4.9%) in Spain if it is to have a significant impact on water consumption (10% reduction), with a 26% reduction in farm income. PERRY (1995) estimated that inducing a 15% reduction in water demand in Egypt through volumetric pricing would decrease farm incomes by 25%. YANG *et al.* (2003) showed that under the current setting of irrigation institutions, the price elasticity of water demand was bound to be low and the adverse effect on rural welfare was large in China. NOÉME and FRAGOSO (2004) concluded that in Portuguese region of Alentejo, the water demand was inelastic when the water prices were relatively reduced, up to 0.02 €/m$^3$ (2%). At this price level there was not any decrease either of the water consumption or of the watering area and crops replacement was not made. When the price 0.02 €/m$^3$ was exceeded, the demand becomes more elastic, and noticeable reductions in the consumption and in the watering area could be seen. Research results concerning irrigation demand elasticities showed that depending on the used methods water demand elasticity for low water price ranges and medium water price ranges lies in -0.06 and -1.00, -0.12 and -0.48, -0.09 and -0.26, and -0.00 and -0.03 in Andalusia, Spain (GARRIDO *et al*., 1997), and -0.04 and -0.27 in La Charente, France (MONTGINOUL and RIEU, 1996). The study by GOMEZ-LIMON *et al.* (2002) concluded that at low water prices, demand did not decrease because farmers did not change their crop areas: water payments did not achieve their objective, as water consumption was not reduced. Results suggested that the threshold would be between 0.019 and 0.049 € depending on which agricultural policy was implemented. Once a certain threshold had been passed, demand behaved with an elastic response to price rises, by substituting water-intensive crops with others that demand less water. The low-medium level of water prices implied that farmers would reduce their income (gross margin) by 15-25% before water use starts to decrease.

Unfortunately, there are very few studies in Greece concerning the irrigation water pricing. LATINOPOULOS *et al*. (2004) utilized the hedonic price method to reveal the implicit value of irrigation water by analyzing agricultural land values in Halkidiki, a typical rural area in Greece. Results showed that, apart from typical value attributes, the agricultural characteristics of the land, including irrigation water availability, had a significant influence on land prices. The marginal value of water for irrigation in Halkidiki was estimated as high as 0.06 € for a cubic meter. Another study by LEKAKIS (1998) showed that access to water resources had not yet been fully regulated in Greece, and the organization of the water management agencies and water suppliers is essentially governed by the civil code. This institutional framework, together with the remarkable hydrologic complexity, which exists in Greece, make impossible to identify any common trends in Greek agricultural water pricing systems.

## CONCLUSIONS

Given that agricultural production in Greece is limited by the availability of water, the results show that the region has implications in contributing to the policy debate for the Greek agriculture.

Some conclusions were made extending the model in long-term level, which would be useful for the policy makers. Specifically, we applied an MCDM model to the region of Xanthi in Greece under four different scenarios: a) World Markets, b) Global Sustainability, c) Provincial Enterprise, and d) Local Stewardship.

The results show that the increase of water price causes almost similar impacts with those that observed in the status quo scenario (CAP 2003). The water demand is inelastic for low prices and does not become the price responsive until higher prices are attained under all scenarios.

Focusing on the goals of this research, we stress that water pricing, as a single instrument for controlling water use, is not a valid means of significantly reducing agricultural water consumption. This is because consumption does not fall until prices reach such a level that farm income and agricultural employment are negatively affected. If water pricing is selected as a policy tool, a significant decrease in water demand and farm income will characterize the agricultural sector. The impact of this decrease on rural areas that are dependent on irrigated agriculture will be catastrophic. Second, when water consumption decreases as a consequence of substitution of crops with high water demands (cotton, sugar beets, and tobacco), there will be a significant loss of employment both directly on farms and indirectly on processing facilities.

The water pricing leads to a significant reduction in fertilizer use as a result of reduced water consumption through changes in crop plans, as less productive crops are introduced. This will obviously have a positive impact on the reduction of non-point chemical pollution by agriculture. But the environmental impact of fertilizer use could also be reduced significantly by improved agricultural practices.

For the reduction of consumption of irrigated water, a sufficient water pricing policy is proposed in combination with the adoption of new irrigation methods and technologies taking into account the particular characteristic of the region (structural factors, agronomic conditions, and financial constraints), and in accordance with the water framework directive and the national water policy. Accompanied measures to reduce and/or efficiently use the irrigated water are regulatory policies such as water metering, licenses and time-limited abstraction permits, and the promotion of appropriate technologies through advice, training and demonstrations of best practice.

Although the study has not included an analysis of 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 a more limited program of investment in new schemes in the future. At the same time, there is a clear scope for improving existing irrigation technology without affecting their selection of crops. A more detailed analysis could help to set priorities for investments in irrigation and associated rural infrastructure in the coming years. Moreover, European Member States have an obligation to exercise a detailed and thorough environmental scrutiny in their local, regional and national appraisal systems to identify potential negative environmental impacts and to take appropriate actions. We think that this area of study constitutes an interesting and important horizon for future research.

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**Table 1. Links between Foresight and agricultural policy scenarios**

| 'Foresight' scenario | Agricultural policy scenario | Intervention regime |
|---|---|---|
| Status Quo | Baseline (CAP 2003) | 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 programs |
| 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 |

Sources: UK foresight program (DTI, 1999, 2002); WADI project (BERBEL et al., 2002; MORRIS and VASILEIOU, 2003)

*Table 2: Technical and economic coefficients of crops during 1995-2001*

| Crop | Wheat | Barley | Corn | Alfalfa | Tobacco | Cotton | Sugar beet | Tomato | Hard wheat | Set aside |
|---|---|---|---|---|---|---|---|---|---|---|
| **Variable** | **X1** | **X2** | **X31** | **X41** | **X51** | **X61** | **X71** | **X81** | **X91** | **SA** |
| **Year** | | | | | | | | | | |
| **Prices perceived by farmers (euro/kg)** | | | | | | | | | | |
| 1995 | 0.13 | 0.13 | 0.10 | 0.10 | 3.64 | 0.82 | 0.03 | 0.08 | 0.13 | - |
| 1996 | 0.14 | 0.14 | 0.14 | 0.12 | 3.64 | 0.84 | 0.05 | 0.08 | 0.15 | - |
| 1997 | 0.12 | 0.12 | 0.12 | 0.12 | 3.22 | 0.67 | 0.05 | 0.07 | 0.12 | - |
| 1998 | 0.12 | 0.13 | 0.12 | 0.12 | 3.35 | 0.70 | 0.06 | 0.07 | 0.12 | - |
| 1999 | 0.12 | 0.13 | 0.12 | 0.12 | 3.49 | 0.73 | 0.06 | 0.08 | 0.12 | - |
| 2000 | 0.13 | 0.14 | 0.13 | 0.13 | 3.64 | 0.76 | 0.06 | 0.08 | 0.13 | - |
| 2001 | 0.15 | 0.15 | 0.14 | 0.16 | 3.33 | 0.28 | 0.05 | 0.08 | 0.15 | - |
| **Yield (kg/ha)** | | | | | | | | | | |
| 1995 | 3,400 | 3,300 | 11,000 | 13,000 | 1,500 | 2,600 | 65,600 | 56,000 | 3,300 | 0 |
| 1996 | 3,400 | 2,900 | 12,000 | 13,000 | 1,500 | 2,800 | 65,700 | 56,500 | 3,100 | 0 |
| 1997 | 3,400 | 2,900 | 11,000 | 13,000 | 1,900 | 2,900 | 65,700 | 56,500 | 3,100 | 0 |
| 1998 | 3,400 | 2,900 | 11,000 | 13,000 | 1,900 | 2,900 | 65,700 | 56,500 | 3,100 | 0 |
| 1999 | 3,400 | 2,900 | 11,000 | 13,000 | 1,900 | 2,900 | 65,700 | 56,500 | 3,100 | 0 |
| 2000 | 3,400 | 2,900 | 11,000 | 13,000 | 1,900 | 2,900 | 65,700 | 56,500 | 3,100 | 0 |
| 2001 | 3,500 | 3,500 | 11,000 | 15,000 | 1,900 | 3,400 | 75,000 | 55,000 | 3,000 | 0 |
| **Subsidies (euro/ha)** | | | | | | | | | | |
| 1995 | 56.4 | 56.4 | 221.9 | - | 4.0 | - | - | - | 334.4 | 124.7 |
| 1996 | 119.3 | 119.3 | 431.8 | - | 4.0 | - | - | - | 438.0 | 152.0 |
| 1997 | 126.7 | 126.7 | 448.2 | - | 4.0 | - | - | - | 509.2 | 195.6 |
| 1998 | 132.0 | 132.0 | 466.8 | - | 4.0 | - | - | - | 530.4 | 203.8 |
| 1999 | 137.5 | 137.5 | 486.3 | - | 4.0 | - | - | - | 552.5 | 212.3 |
| 2000 | 143.2 | 143.2 | 506.6 | - | 4.0 | 0.2 | - | - | 575.6 | 221.1 |
| 2001 | 155.5 | 155.5 | 563.2 | - | 4.0 | 0.6 | 0.01 | - | 501.8 | 221.1 |
| **Income (euro/ha)** | | | | | | | | | | |
| 1995 | 498 | 485 | 1,322 | 1,300 | 11,475 | 2,132 | 3,280 | 4,480 | 763 | 221 |
| 1996 | 595 | 525 | 2,112 | 1,560 | 11,475 | 2,352 | 3,285 | 4,520 | 903 | 221 |
| 1997 | 518 | 486 | 1,713 | 1,495 | 12,776 | 2,463 | 3,488 | 3,999 | 866 | 196 |
| 1998 | 539 | 506 | 1,785 | 1,558 | 13,308 | 2,566 | 3,633 | 4,166 | 902 | 204 |
| 1999 | 562 | 527 | 1,859 | 1,622 | 13,862 | 2,673 | 3,784 | 4,339 | 939 | 212 |
| 2000 | 585 | 549 | 1,937 | 1,690 | 14,440 | 2,784 | 3,942 | 4,520 | 979 | 221 |
| 2001 | 681 | 681 | 2,103 | 2,400 | 13,946 | 2,958 | 4,235 | 4,400 | 952 | 221 |
| **Variable costs (euro/ha)** | | | | | | | | | | |
| 1995 | 218 | 186 | 655 | 408 | 6,415 | 822 | 1,100 | 1,951 | 235 | 16 |
| 1996 | 254 | 208 | 629 | 503 | 6,516 | 965 | 1,252 | 1,825 | 271 | 16 |
| 1997 | 275 | 257 | 796 | 411 | 6,625 | 1,023 | 1,342 | 1,902 | 277 | 19 |
| 1998 | 286 | 268 | 829 | 428 | 6,901 | 1,066 | 1,398 | 1,981 | 289 | 19 |
| 1999 | 298 | 279 | 864 | 446 | 7,189 | 1,110 | 1,456 | 2,063 | 301 | 20 |
| 2000 | 310 | 291 | 900 | 465 | 7,488 | 1,156 | 1,517 | 2,149 | 313 | 21 |
| 2001 | 323 | 303 | 937 | 484 | 7,800 | 1,205 | 1,580 | 2,238 | 326 | 22 |
| **Gross margin current (euro/ha)** | | | | | | | | | | |
| 1995 | 280 | 300 | 667 | 892 | 5,060 | 1,310 | 2,180 | 2,529 | 529 | 205 |
| 1996 | 341 | 317 | 1,483 | 1,057 | 4,959 | 1,387 | 2,033 | 2,656 | 632 | 205 |
| 1997 | 243 | 229 | 917 | 1,084 | 6,151 | 1,440 | 2,145 | 2,097 | 589 | 177 |
| 1998 | 253 | 238 | 955 | 1,129 | 6,407 | 1,500 | 2,235 | 2,185 | 613 | 184 |
| 1999 | 264 | 248 | 995 | 1,176 | 6,674 | 1,563 | 2,328 | 2,276 | 639 | 192 |
| 2000 | 275 | 258 | 1,037 | 1,225 | 6,952 | 1,628 | 2,425 | 2,371 | 665 | 200 |
| 2001 | 357 | 378 | 1,166 | 1,916 | 6,146 | 1,754 | 2,654 | 2,161 | 626 | 199 |
| **Mean** | 288 | 281 | 1,031 | 1,211 | 6,050 | 1,511 | 2,098 | 2,325 | 613 | 195 |
| **Labor (hours/ha)** | | | | | | | | | | |
| | 25 | 25 | 150 | 130 | 3,200 | 230 | 250 | 360 | 25 | 10 |
| **Fertilizers (kg/ha)** | | | | | | | | | | |
| | 500 | 500 | 900 | 1000 | 700 | 650 | 1500 | 900 | 500 | 0 |

Sources: Statistical Yearbooks of Greece 1995-2001; Field and processed data

**Table 3: Existing and possible prices for agricultural inputs and outputs under alternative agricultural policy scenarios by 2010 (expressed as a % of existing year 2001 at constant values)**

| | Existing (2001) | World agricultural markets | Global agricultural sustainability | Provincial agriculture | Local community agriculture |
|---|---|---|---|---|---|
| **Crops:** | | | | | |
| Grains and oil | 100 | 85-95 | 95-105 | 105-115 | 115-125 |
| Wheat | 100 | 85-95 | 95-105 | 105-115 | 115-125 |
| Barley | 100 | 0 | 95 | 100 | 100 |
| Cereal area subsidy | 100 | 90-100 | 100-110 | 105-115 | 105-115 |
| Maize | 100 | 0 | 75-85 | 90-100 | 85-95 |
| Maize area subsidy | 100 | 85-95 | 95-105 | 110-110 | 110-120 |
| Rice | 100 | 80 | 100 | 100 | 110-120 |
| Set aside subsidy | 100 | 0 | 95 | 100 | 105 |
| Set aside quota | 100 | 85-95 | 90-95 | 95-105 | 105-110 |
| **Roots:** | | | | | |
| Sugar beet | 100 | 85-95 | 110-120 | 100-110 | 120-130 |
| Vegetable and Salad | 100 | 90-100 | 100-110 | 105415 | 125-135 |
| Tomatoes | 100 | 90-100 | 100-110 | 105-115 | 125-135 |
| **Tree fruits:** | | | | | |
| Apples | 100 | 90-100 | 100-110 | 105-115 | 125-135 |
| Pears | 100 | 85-95 | 90-100 | 90-100 | 105-115 |
| Peaches | 100 | 75-85 | 85-95 | 80-90 | 105-115 |
| Tobacco | 100 | 0 | 85 | 90 | 105 |
| Cotton | 100 | 85-100 | 130-140 | 100-110 | 150-170 |
| Cotton subsidy | 100 | 85-95 | 135-145 | 100-110 | 140-150 |
| **Inputs prices:** | | | | | |
| Fertilizers | 100 | 85-100 | 140-150 | 100-110 | 150-160 |
| Pesticides | 100 | 110-120 | 100-105 | 105-115 | 95-100 |
| Energy | 100 | 85-95 | 120-130 | 100-110 | 130-140 |
| Seeds | 100 | 100-110 | 110-120 | 120-130 | 130-140 |
| Machinery | 100 | 100-115 | 115-135 | 100-115 | 120-140 |
| Contractor services | 100 | 130-135 | 120-130 | 130-140 | 110-120 |
| Water prices | 100 | 100-110 | 115-130 | 100-110 | 120-140 |
| Irrigation | 100 | 100-110 | 120-130 | 115-125 | 130-150 |
| Labor | 100 | 90-100 | 100-110 | 95-105 | 110-120 |
| Land | 100 | 110-120 | 110-125 | 100-110 | 85-95 |
| Other inputs | 100 | 85-95 | 125-135 | 85-95 | 130-140 |
| Crop yield changes due to technology | 100 | 110-120 | 100-115 | 100-105 | 85-105 |
| Restriction on chemical use | 100 | 130-140 | 120-130 | 110-120 | 100-110 |

Source: Survey and extrapolated data

**Table 4: Pay-off matrix for the selected region**

| Values | Optimum | | | Real (existing farm plan) |
|---|---|---|---|---|
| | GM | VAR | LAB | |
| Gross margin (GM) | 186828 | 100553 | 95670 | 155615 |
| Minimization of risk (VAR) | 170494752 | 29915124 | 35563420 | 192800310 |
| Minimization of labor (LAB) | 41092 | 10043 | 7594 | 36358 |

Source: Results of the study

**Table 5. Crop distributions in response to changes in water price in status quo**

| Crops | Variable | Water price (€/m$^3$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.00 | 0.01 | 0.02 | 0.03 | 0.05 | 0.07 | 0.09 | 0.11 | 0.13 | 0.15 |
| Soft wheat | X1 | - | - | - | - | - | - | - | - | - | - |
| Barley | X2 | - | - | - | - | - | - | - | - | - | - |
| Maize | X31 | - | - | - | - | - | - | - | - | - | - |
| | X32 | - | - | - | - | - | - | - | - | - | - |
| | X33 | 36.80 | 36.80 | 36.80 | 36.80 | - | - | - | - | - | - |
| Alfalfa | X41 | - | - | - | - | - | - | - | - | - | - |
| | X42 | - | - | - | - | 11.50 | 11.50 | 11.50 | 11.50 | 11.50 | 11.50 |
| | X43 | 11.50 | 11.50 | 11.50 | 11.50 | - | - | - | - | - | - |
| Tobacco | X51 | - | - | - | - | - | - | - | - | - | - |
| | X52 | 8.20 | 6.37 | 5.83 | 5.29 | 8.03 | 7.52 | 7.02 | 8.20 | 8.20 | 8.20 |
| | X53 | - | - | - | - | - | - | - | - | - | - |
| Cotton | X61 | - | - | - | - | - | - | - | - | - | - |
| | X62 | 15.30 | 15.30 | 15.30 | 15.30 | 15.30 | 15.30 | 15.30 | 5.86 | 3.78 | 1.97 |
| | X63 | - | - | - | - | - | - | - | - | - | - |
| Sugar beet | X71 | - | - | - | - | - | - | - | - | - | - |
| | X72 | 2.20 | 2.20 | 2.20 | 2.20 | 2.20 | 2.20 | 2.20 | 2.20 | 2.20 | 2.20 |
| Tomato | X81 | - | - | - | - | - | - | - | - | - | - |
| | X82 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 |
| Hard wheat | X91 | 11.20 | 12.87 | 13.36 | 13.85 | 48.15 | 48.62 | 49.08 | 56.58 | 58.47 | 60.00 |
| Set aside | SA | 4.80 | 4.97 | 5.02 | 5.06 | 4.82 | 4.86 | 4.91 | 5.66 | 5.85 | 6.13 |

Source: Results of the study

**Table 6. Crop distributions by scenario at zero €/m$^3$ water price level**

| Simulated crops areas (100 ha) | Status quo | World market | Global sustainability | Provincial enterprise | Local stewardship |
|---|---|---|---|---|---|
| Wheat | - | - | - | - | - |
| Barley | - | - | - | - | - |
| Corn | 36.8 | 36.8 | 36.8 | 36.8 | 36.8 |
| Alfalfa | 11.5 | 11.5 | 11.5 | 11.5 | 11.5 |
| Tobacco | 8.2 | 8.2 | 8.2 | 8.2 | 8.2 |
| Cotton | 15.3 | 2.10 | 15.3 | 15.3 | 15.3 |
| Sugar beet | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| Tomato | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| Hard wheat | 11.2 | 23.2 | 11.2 | 11.2 | 11.2 |
| Set Aside | 4.8 | 6.0 | 4.8 | 4.8 | 4.8 |

Source: Results of the study

**Table 7. Indicators-scenario for the farmers at water price level zero €/m$^3$**

| Scenario | Economic balance | | Social impact | | Landscape and biodiversity | | Water use (m$^3$/ha) | Environmental impact | |
|---|---|---|---|---|---|---|---|---|---|
| | Farm income (€/ha) | Public support (€/ha) | Farm employment (man-days/ha) | Seasonality (man-days /month) | Genetic diversity (no. of crops) | Soil cover (month/ year) | | Nitrogen balance (kg/ha) | Energy balance ($10^5$ kcal/ha) |
| Status quo | 2103.8 | 200.89 | 421.85 | 60.26 | 7 | 7 | 4462.0 | 4.00 | 175.56 |
| World market | 1822.6 | 200.94 | 355.1 | 50.73 | 7 | 7 | 3515.0 | 3.93 | 175.57 |
| Global sustainability | 2424.4 | 200.89 | 421.85 | 60.26 | 8 | 7 | 4462.0 | 3.93 | 175.56 |
| Provincial enterprise | 2280.3 | 209.54 | 421.85 | 70.31 | 7 | 6 | 4462.0 | 3.90 | 177.51 |
| Local stewardship | 1561.34 | 209.54 | 421.85 | 70.31 | 7 | 6 | 4462.0 | 3.90 | 177.51 |

Source: Results of the study

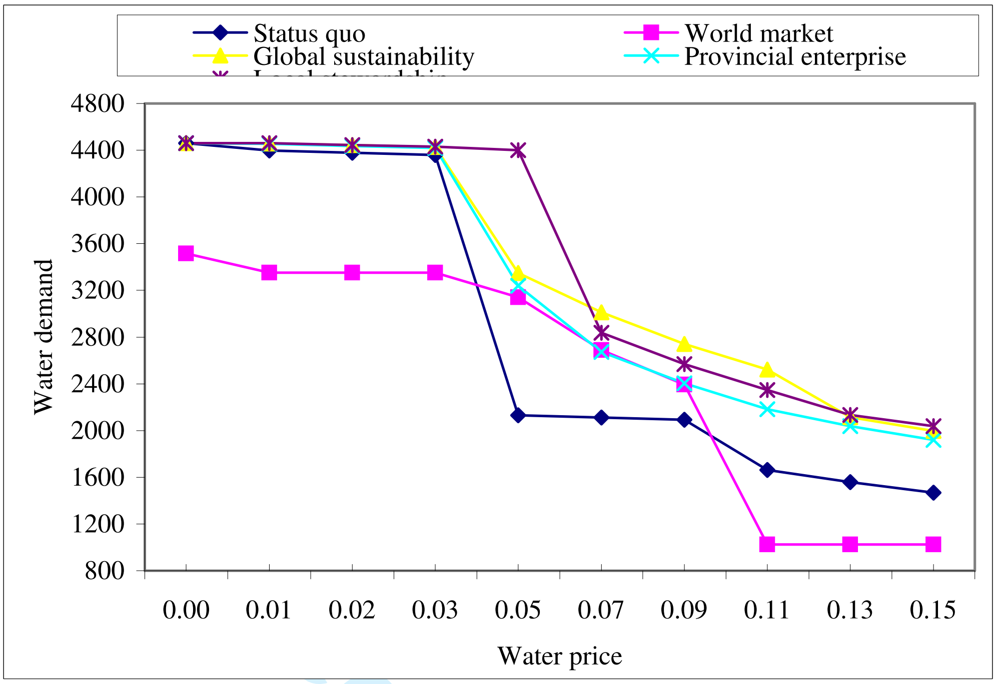


**Figure 1. Water demand (m³/ha) among scenarios in relation to water price (€/m³)**

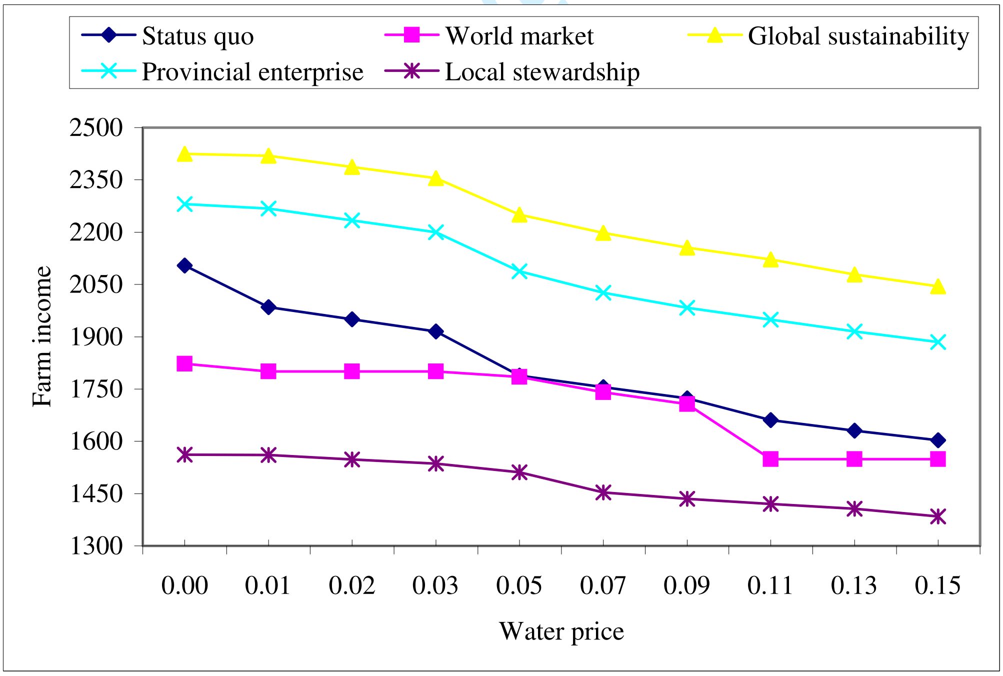


**Figure 2. Farm income (€/ha) among scenarios in relation to water price (€/m³)**

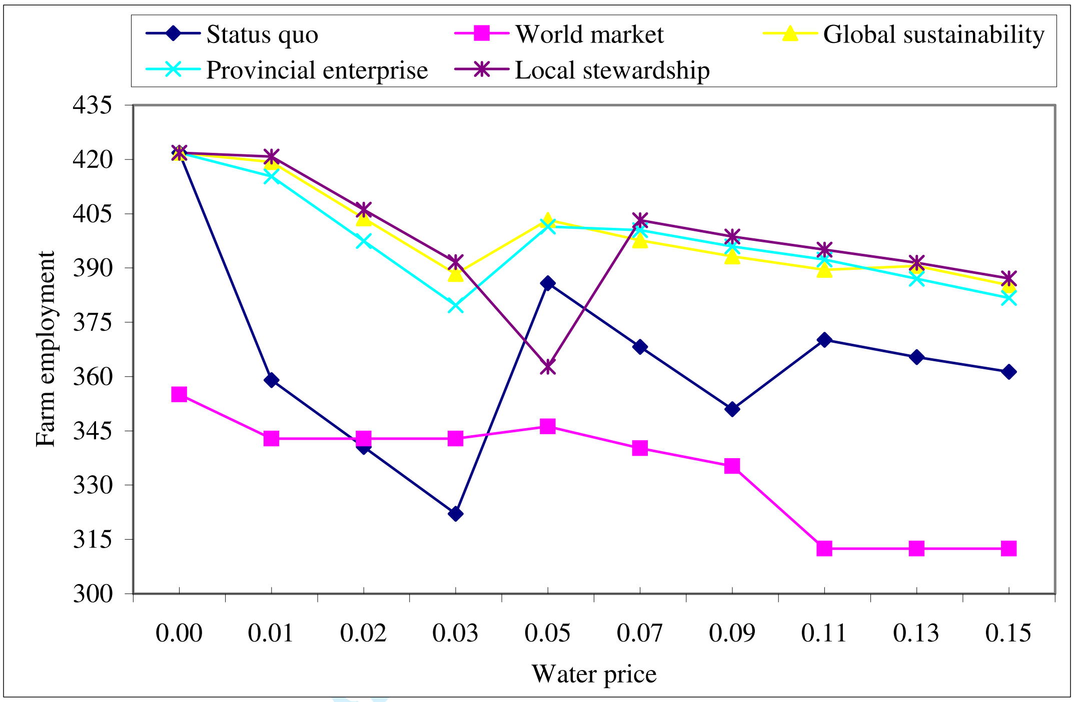


**Figure 3. Farm employment (man-days/ha) among scenarios in relation to water price (€/m$^3$)**

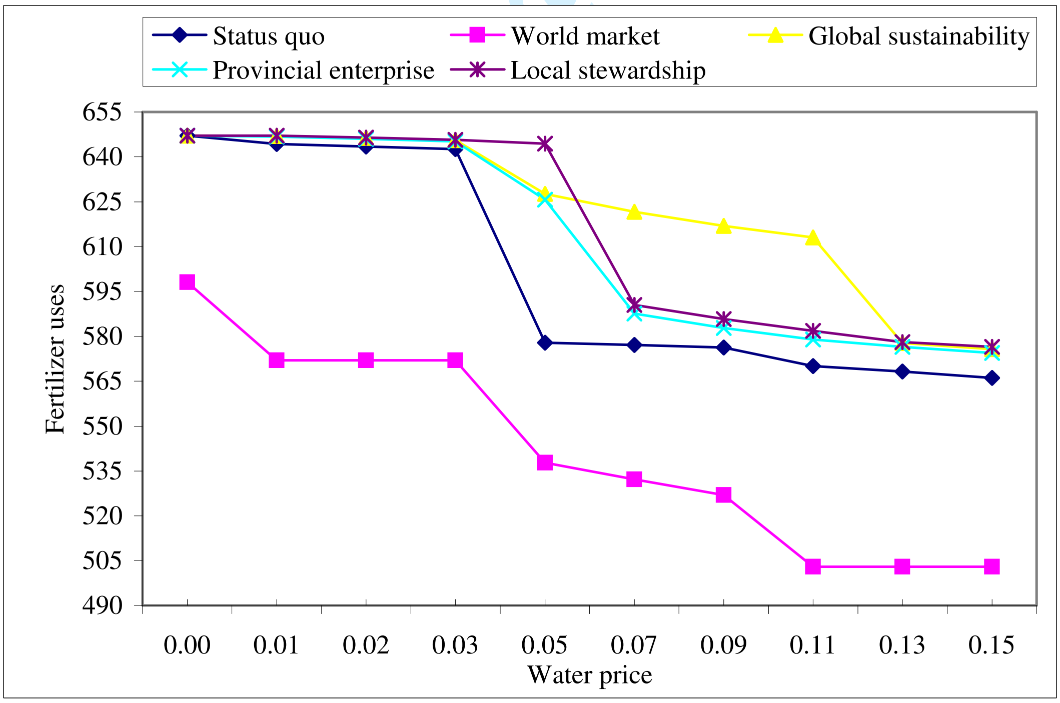


**Figure 4. Fertilizer use (kg/ha) among scenarios in relation to water price (€/m$^3$)**