Simulation of impacts of irrigated agriculture on income, employment and environment

Basil Manos, Jason Papathanasiou, Thomas Bournaris, Anastasia Paparrizou
Department of Agricultural Economics, Aristotle University of Thessaloniki, Greece

Abstract
This paper uses a Multicriteria Mathematical Programming model to estimate the farmer's utility function and simulate different scenarios and policies as well as to make alternative production plans. Application of this model was carried out in the entire irrigated region of the Xanthi Prefecture in Greece, as well as to three farm types of varying size. The three farms types, small, medium and large, were the result of a cluster analysis into a sample of farms of the region. In all these four cases, we considered three criteria for the estimation of the utility function; the maximization of total gross margin, the minimization of its variance and the minimization of labor. The estimated utility functions were used as objective functions of Linear or Quadratic (when the variance is considered) Programming models in order to find the optimum production plan of the total region and each farm type separately. These models were used to simulate the impacts on the production plan, income, employment and the environment due to a policy, which increases the price of irrigation water.
Key words: Simulation, Multicriteria analysis, Mathematical Programming

1. Introduction

The planning of agricultural production takes place with the use of Linear or Non Linear Programming, which usually maximizes total gross margin. However, the use of only one criterion, such as the maximization of total gross margin, is not sufficient to interpret farmers' behavior. It should be obvious, that farmers are not only interested in the maximization of total gross margin, but also in other conflicting criteria, such as the minimization of the variance of total gross margin, the minimization of labor, the minimization of the variable cost, the minimization of fertilizer, the minimization of the amount of water used for irrigation etc. These criteria, either some or all, can be incorporated into one unique utility function.

This variety of criteria, taken into consideration by farmers when planning their productive activities, explains the interest in the use of multicriteria decision making methods (MCDM). Thus the allocation of agricultural production factors (soil, labor, capital, water etc.) entails the simultaneous optimization of a number of conflicting criteria. In addition, the simulation of the most realistic decision-making processes leads to concrete simulation scenarios and consequently to better processes of policy application [Berbel and Rodriguez-Ocana (1998); Gomez-Limon and Berbel (2000); Berbel and Gomez-Limon (2000); Gomez-Limon *et al*. (2002); Arriaza *et al*. (2001); Gasson (1973); Patrick and Blake (1980); Herath (1981); Cary and Holmes (1982); Sumpsi *et al*. (1991) & (1993); Gomez-Limon and Berbel (1995); Amador *et al*. (1998)]. Combining the simplicity and flexibility of Linear Programming with the environment of MCDM models, we applied a Weighted Goal Programming model for policy analysis [Romero and Rehman (1989); Rehman and Romero (1993); Romero and Rehman (2003)].

This model has been applied to the irrigated area of the Xanthi Prefecture in Greece. The main crops of this region are maize, cotton, hard wheat, alfalfa and tobacco. Agricultural land consists of a combination of fertile and poor soil. The existent production plan of the selected region is given in Table 1.

The model is also applied to three different types of farms found in the region, specifically to small, medium and large farms, for comparison at the farm level. In order to categorize these three farm types (clusters) and derive their corresponding representative farm, we applied the Hierarchical Cluster Analysis to a sample of farms in the study region. The clustering took into consideration all the available data of the farms with regard to social, economic and technical variables, such as family size, farm size, farmers' age, crop distribution in the production plan, machinery, irrigation technology (types and methods of irrigation), variable cost, fertilizer and labor use, crop yield, income and gross margin (Table 1). The main characteristic of each cluster was farm size. This is in accordance with the farm typology in Greece that depends highly on farm size. This is due to two reasons. First, farm size in Greece is closely related with 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% farm size between 0-5 ha and only 23% farm size over 5 ha). The first farm type (first cluster) is comprised of mainly small producers (up to 5 hectares). Primarily tobacco and cereals constitute the production plan of this farm type. Tomatoes and sugar beets are not included. The second cluster (5 to 10 hectares) i.e. the medium farms have a similar plan to that of small farms but now sugar beets and tomatoes are included while cotton is cultivated in a greater area. In their production plan large farms (over 10 hectares), produce primarily maize, cotton and cereals, whereas they do not include tobacco, barley or alfalfa.

2. Model specification

Different methodologies have been developed for the analysis and simulation of systems in agricultural production based on multicriteria techniques [Sumpsi *et al*. (1991) & (1993) and Amador *et al*. (1998)] which propose Weighted Goal Programming as the most suitable approach for the analysis of decision-making. This methodology has been successfully applied to real rural systems [Manos and Kitsopanidis (1986); Manos and Kitsopanidis (1988); Manos (1991); Gomez-Limon and Berbel (1995); Berbel and Rodriguez-Ocana (1998), Manos *et al*. (2002a); Manos *et al*. (2002b); Manos *et al*. (2002c)].

In this study, we applied Weighted Goal Programming to estimate the utility function, in order to simulate farmers' decision-making processes and then to simulate different scenarios and policies and make alternative production plans.

The methodology includes the following steps:

a. Determination of a set of objectives f_1 (X), f_2 (X).. . f_n (X) that represent the most important farmers' objectives (e.g. maximization of gross margin, minimization of risk, minimization of labor use).

b. Definition and estimation of the pay-off matrix for the above set of objectives which has the following form (1):

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

The elements of this matrix are estimated by optimizing one objective in each row subject to a set of constraints which are based on CAP, marketing and agronomic conditions in the study region (see section 3 below). Thus f_{ij} is the value of the i-th attribute when the j-th objective is optimized.

c. Use of the pay-off matrix to estimate a set of weights w_j that reflect the farmers' preferences in the best possible way. For this we solve the following Linear Programming model (2):

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

subject to (2)

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

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

where, w_j is the weight that is attached to each objective j (j=1,2….,q) of the farmer, f_{ij} are the elements of the pay-off matrix, f_i is the value that is achieved for the i-th objective with the existing production plan, p_i represents the positive deviation from the i-th objective and n_i the negative deviation (Romero, 1991).

We selected 3 objectives that were considered to be part of a farmer's decision-making process.

Maximization of gross margin:

$$GM = \sum GM_i * X_i$$

where X_i is the area of the i-th crop in hectares and GM_i is gross margin of the i-th crop in euro per hectare. GM is the seven years average.

Minimization of risk:

$$TotalRisk = \overline{x_i'}[Cov]\overline{x_i}$$

where [Cov] is the variance/covariance of gross margin during the period of 7 years, and x_i is the vector of area of each crop in hectares. In our case the risk is measured as the variance of the total GM.

Minimization of labor:

$$TL = \Sigma\, TL_i * X_i$$

Labor is calculated as the sum of labor for all activities (TL) in each crop.

The constraints of the model are referred to the Total cultivable area, to the Common Agricultural Policy (CAP), to the Market conditions, to Rotational and agronomic considerations etc

We have also included some attributes of great interest which are considered as a function of decision variables. The attributes that are analyzed are:

Water consumption: The projected water consumption is measured in m^3/ha. In Greece there is scarcity in irrigation water and for that reason the policy makers wish to control water consumption as a consequence of changes in water management policy.

Economic impact: We measure the economic impact on the change of policy by calculating two variables: agricultural income and public sector revenue from water pricing, both calculated in €/ ha.

Social impact: Since irrigated agriculture is one of the main sources of employment in the study region, any change in the policy will influence to a considerable extent the social structure of rural areas. This attribute is measured in man-hours per hectare (hours/hectare).

Environmental impact: The main environmental impact on irrigated agriculture is water consumption itself, with the creation of a mosaic landscape and an increase in both crop diversity and moist areas. Besides these positive impacts however, an increase in the use of fertilizers and chemicals has negative results as they are the main source of pollution in agriculture. We use the demand for fertilizers as an indicator of the environmental impact on irrigated agriculture, measured in kilograms of nitrogen added per hectare (N/ha).

We note that in order to give the system as much freedom as possible regarding the use of land and the distribution of irrigation water, each crop was tested at two or three different levels of water supply, giving farmers the opportunity to select one of these levels (Table 2).

We also estimated fertilizer use (nitrogen) even if it is not a relevant attribute for the farmers, since they consider it as a variable of cost and not as a decision variable. However, this attribute is important for policy analysis, as it can interpret the environmental impact. There is also a detailed analysis of water demand and labor use, as these two attributes are included in the model, more specifically, labor use in the objective function and water demand in the system of constraints.

3. Data

The data refer to a period of 7 years (1995-2001) and were collected from the villages and municipalities of the study region, the Prefecture of Xanthi, the Ministry of Agriculture, the National Statistical Service and from the Secretariat of the Region of Eastern Macedonia and Thrace. The technical coefficients of crops were gathered from a sample of farms of the region using a questionnaire. We also used additional data provided by the Department of Agricultural Economics of the Aristotle University of Thessaloniki.

We focused our research on cereals and industrial crops, which represent the largest amount of the irrigated production in the study region (Table 1). In terms of farmers' decision-making processes, the choice of these crops are dependent on both natural and cultivation conditions which are determined by technical and economic parameters such as prices, yields, subsidies, gross returns, variable costs and gross margins. The crops in table 1 constitute the set of decision variables X_i. The set aside (SA) activity, which is related to the subsidized crops and CAP policy, is also included in the decision variables set.These variables can take any value from the feasible set.

The prices of crop products are the average for the region, which were obtained from official statistics. We used historical time series data for the period 1995-2001, where the prices were adjusted for inflation (2001 prices). The subsidies depend on the Common Agricultural Policy (CAP) and the corresponding data were collected from official publications.

The variable cost includes 6 categories of expenses: seeds, fertilizers, chemicals, machinery, labor and cost of irrigation water. More specifically, cost of irrigation water includes the cost paid to the Local Organization of Land Improvements (TOEB), cost of electricity/fuels for pumping and a water price (from zero to 0.15 €/m^3) which we considered as the simulated water price. As regards the costs of all other inputs (labor, fertilizer etc.) they are the product of the required per hectare quantity per each crop multiplied by its corresponding price.

4. Model application

The pay-off matrix for the study region is presented in Table 3. Similar pay-off matrices have been calculated for each of the three farm types.

We can observe, from Table 3, a significant degree of compatibility between the second and third objective which are both in strong conflict with the first objective. Specifically, the optimum farm plan when single objective is labor minimization almost coincides with the optimum plan when single objective is labor minimization. Both these optimum plans are very different as regards the achieved level of gross margin, variance and labor with the optimum farm plan resulted when single objective is gross margin maximization. On the other hand, the last column shows the real data (that have been observed) in the study region. These values show the actual crop distribution in the region (taking into consideration the theoretical value of 100 ha per farm) and the relationship between different crops and the examined objectives [GM, risk (VAR) and TL]. We can see the actual distance between the real situation from each separate optimum (column). This can prompt us to try a combination of the three objectives, as a better simulation of the farmer's behavior.

The weights that best represent the farmers' preferences in the total region and the 3 farm types are given in Table 4. We observe that in the entire region, the minimization of total labor is considered an important criterion since it has a weight of 3.9%. This is combined with the criterion of the maximization of gross margin that presents a very large weight (96.1%). In contrast, risk is not considered as a relative criterion in this production system which includes maize as the main crop.

The estimation of these weights was based on the existing situation, where the water price is zero. These weights correspond to the psychological attributes of producers and therefore we may suppose that they will remain at the same level in both the medium and long terms.

In order to simulate different scenarios of water price, we used the weights of Table 3, in order to find farmers' utility function. The utility function for the total region is:

U = 96,1% GM –3,9% LAB **(3)**

If we use the "normalized weights" instead of percentages [Sumpsi *et al*. (1997)], the utility function takes the form (5) and then dividing by 10^{-10}, the final utility function can be expressed as follows (6):

$$U = 1{,}238 \times 10^{-5} GM - 1{,}28 \times 10^{-6} LAB \qquad \textbf{(4)}$$

$$U = 12{,}38 GM - 1{,}28 LAB \qquad \textbf{(5)}$$

The corresponding utility functions for the 3 farm types are:

Small farms: U = 83.9% GM –1.7%VAR – 14.4% LAB **(6)**

Medium farms: U = 83.4%GM –14.3%VAR –2.3% LAB **(7)**

Large farms: U = 52.3% GM –28.9% VAR –18.8% LAB **(8)**

We observe that both in the total region and the three farm types the most important criterion appears to be total gross margin and circumstantially the labor used. The risk of gross margin as the third criterion appears to be important for medium farms but more particularly for large farms. This result seems to be in accordance with agricultural practice.

The estimated utility functions for the total region and the 3 farm types were then used as objective functions of MCDA Linear Programming or Quadratic Programming models (when the variance is entered) in order to obtain the optimum production plan of the total region as well as each farm type separately. The optimum production plan for the total region is given in Table 5. In this table the existing production plan is also presented and is compared to the plan obtained by the MCDM model.

The adopted methodology appears to be a good approach for the observed values at the present water price (zero). The MCDM model in attempting to combine the two objectives, the maximization of gross margin and the minimization of risk, gives a production plan that attains 19.7% more gross margin, a variance of gross margin of 20.7% less and total labor 11.1% more than the existing plan. The MCDM models for the 3 farm types give similar results.

5. Results

The estimated utility functions for the total region and the three farm types were used to estimate the cost of water required for the production of irrigated crops with the help of the MCDM model and the following additional presuppositions:

1. The function to be maximized is function (5) for the total region and functions (6), (7) and (8) for the three farm types;
2. Gross margin includes the additional cost of water, and;
3. Crops that need different levels of irrigation were introduced in order to allow the system to be adapted to the increasing cost of irrigation (Table 2).

We can see in Table 2 that crops maize, alfalfa, tobacco, cotton, sugar beets and tomatoes are represented with two or three different decision variables according to how many varieties from each crop are cultivated in the study region. For example, maize is found in the region at three different varieties. They are identified in Table 2 as X31, X32 and X33. The corresponding data are the required inputs to produce each crop and variety. The water demand represents the quantity (thousands) in cubic meters consumed per hectare of land. For different levels of water, the crops have different or same yields. For example, maize X_{31} means maize irrigated with 8,500 m^3/ha and producing 11,000 kg/ha, whereas maize X_{32} means maize irrigated with 7,200 m^3/ha and producing the same amount 11,000 kg/ha, etc..

We also included non-irrigated crops such as wheat zero and barley zero that means irrigation only from the regular rainfall conditions. Finally, the land in set aside is considered as another activity connected with production planning. As a result, a number of various crops (wheat, barley, maize, alfalfa, tobacco, cotton, sugar beets and tomatoes) constitute the decision variables, one of each combined with a level of water supply. Each of these modified irrigated crops includes technical and economic coefficients such as, labor, fertilizers as well as the remaining input data.

In continuation the MCDM model was used for the investigation of impact of water price on the production plans of the total region as well as on the three farm types. In addition, it was used in order to examine the impact on the consumption of water, farmers' income, employment and the environment due to a policy of an increase in irrigated water prices.

Consumption of water

In Figure 1 appears the change to water demand in both the total region and the three farm types due to a change in water price from the present level (zero) up to 0.15 €/m^3. The figure represents a formal demand curve that shows how the farmer adapts to the increasing costs of production as a consequence of a rise in water prices. We can see that multicriteria demand begins from 0.03 €/m^3 (in case of cluster 3 the starting point is 0.01 €/m^3). Progress is smooth and irrigated cultivation remains constant until the price of water reaches 0.15 €/m^3. The smooth curve of the multicriteria demand function is explained by production plans that include a smaller number of crops when gross margin is the only objective, and then, as is known, only the most profitable crops are included in the production plan. On the other hand, when the minimization of labor is taken into consideration, such as in the utility function (6), the farmer tries to differentiate his activities by introducing a greater variety of crops in the production plan.

The different demand curve of water is due to changes in the production plan (Table 6), as an adaptation to the increasing cost of water resources: low water prices suggest that crops maize (X33) and alfalfa (X43) planted require a high consumption of water. However, when water price increases and especially above price 0.03 €/m^3 maize (X33) and alfalfa (X43) are replaced by alfalfa (X42). Cotton presents an important decrease above price 0.09 €/m^3, while hard wheat present a continuous increase from the beginning of multicriteria demand.

Economic impact

Figure 2 and Table 7 show that there is a serious reduction in farm income as a result of a continuous increase in the price of water. This reduction is a result of two factors which operate in the same direction:

1. The transfer of income from the agricultural to the public sector due to the increase of public revenue from the payments for water, with the intention to redistribute the income for environmental works or integrated regional development. However, it does stop to be an additional weight for the farmer.
2. The continuous increase in water prices means that farmers change their production plans in an attempt to decrease the consumption of water, by introducing less profitable crops as substitutes to costly crops that require larger amounts of water. This process decreases farm income considerably (reduction in income from sales is much greater than the reduction in costs).

As we can clearly see from Figure 2 the income of both the total region and the three farm types are affected by the increase in water prices. They all present a similar small decrease in their income continuously from the beginning of multicriteria process.

Social impact

In micro-terms, an increase in the price of water results in a serious reduction in farm employment as a consequence of producers' reactions to decrease the consumption of water by changing the type of crops used in their production plans. In many cases crops which have a high labor cost are replaced. This implies that crops which require intensive irrigation, like alfalfa (X43) and maize (X33), will be replaced by alfalfa (X42) and hard wheat (X91) requiring less water but which are more mechanized. This change, in relation to labor, can be observed in Figure 3 and Table 7, where we see the farmer's behavior when demand is based on the MCDM model.

Figure 3 shows that water price under 0.01 €/m^3 is characterized by a relatively stable production plan without significant diversification in labor demand. On the other hand, above this minimum price limit, production plans change, inducing a large fall in labor demand. Finally, at the price of 0.05 €/m^3 and above, the production plan is again characterized by a relatively stable number of crops without significant diversification in labor demand.

Environmental impact

The increasing cost of water leads to a significant reduction of fertilizer use as a result of changes in production plans and the inclusion of less productive crops (Table 7, Figure 4). It is obvious that as farmers replace the crop alfalfa (X43) by alfalfa (X42) and hard wheat (X91) in order to save water, the use of fertilizers decreases. At the beginning of the process there is a small increase in fertilizer use as water prices increase from zero to 0.03 €/m^3. Further increases in water prices (above the 0.03 €/m^3) have as a result the important decrease of fertilizer use from 1337.8 kg/ha to 1191.4 kg/ha.

Landscape, biodiversity and energy

Finally, in Table 7 we can see the effect on water price in certain other important indicators relevant to energy, landscape and biodiversity as the genetic diversity, the soil cover and the energy balance. The results indicate that if water prices are increased then genetic diversity and soil cover by the crops is declined. For any increase in water price above 0.05 €/m^3 to 0.15 €/m^3 soils are covered for 6 months, which remains unchanged. On the other hand, energy balance presents a small increase at the beginning of the simulation. However, above the price 0.03 €/m^3 energy balance presents a continuous and important reduction from 206.3 to 140.1 (X10^5) kcal/ha.

6. Conclusions

We applied a Multicriteria Mathematical Programming model in a farm region in

Greece to make alternative production plans and to simulate different water pricing policies. We considered three criteria for that, the maximization of total gross margin, the minimization of its risk and the minimization of labor. The result showed that the most important criterion is total gross margin and circumstantially labor and risk of gross margin.

The results of simulation showed that when water prices are increased important changes occur in farm plans. Specifically, crops with high water requirements are substituted by others less water demanded. This fact will have as a consequence that thereinafter a significant decrease in water demand and farm income will characterize agriculture in the study region. Moreover, it will result to a significant loss of employment both directly on farms and indirectly on processing facilities. The water pricing also 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.

Focusing on the goals of this research, we conclude, that though a sufficient water pricing policy as a single instrument is not enough, however it could reduce significantly the consumption of irrigated water. Therefore a water pricing policy is proposed in combination with an improvement of agricultural practices and the adoption of new technologies taking into account the particular characteristic of the region, and in accordance with the water framework directive and the national water policy.

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Table 1. Socio economic data and production plan of Total and Clusters in the study region

XANTHI	Total	Small farms	Medium farms	Large farms
Farm size average	3.8	1.8	6.0	18.5
Family size	2.5	2.7	2.1	2.7
Seasonal workers per farm	3.9	3.0	4.7	6.0
Tractors per farm	1.1	0.9	1.1	1.7
Irrigation Technology methods				
▪ Gravity	✓	✓	✓	✓
▪ Pressure	✓			
Irrigation Methods				
▪ Surface irrigation	✓	✓	✓	✓
▪ Sprinkler irrigation	✓		✓	
▪ Reel/Gun	✓	✓	✓	✓
▪ Drops irrigation	✓	✓	✓	
Production Plan				
WHEAT	12.0	10.9	11.5	13.1
BARLEY	1.6	2.9	3.0	0.0
MAIZE	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 BEETS	2.1	0.0	2.9	3.3
TOMATOES	1.9	0.0	0.4	4.1
TOTAL	100.0	100.0	100.0	100.0

Table 2. Crops with Different Levels of Irrigation in the Study Region

Crops	Water demand (m^3/ha)	Variables	Yield (kg/ha)	Labor (hours/ha)	Fertilizers (kg/ha)
Wheat soft	0	X1	3500	25	500
Barley	0	X2	3500	25	500
	8500	X31	11000	150	900
	7200	X32	11000	120	765
Maize	5700	X33	12500	120	600
	7000	X41	15000	130	1000
	6000	X42	15000	120	860
Alfalfa	8000	X43	15000	80	1140
	4000	X51	1900	3200	700
	3500	X52	2100	3450	610
Tobacco	0	X53	1200	3000	150
	6000	X61	3400	230	650
	5000	X62	3800	250	540
Cotton	5500	X63	3400	200	600
	4800	X71	75000	250	1500
Sugar beets	4200	X72	75000	230	1300
	3450	X81	55000	250	900
Tomatoes	3000	X82	68000	200	780
Wheat hard	0	X91	3000	25	500
Set aside	0	SA	0	10	0

Table 3. Pay-off Matrix for the Total Region

Values	Optimum			Real (Existing production plan)
	GM	VAR	TL	
GM	171,902	94,251	96,387	155,615
VAR	198,293,838	22,478,166	57,900,076	192,800,310
TL	37,999	14,028	7,524	36,358

Table 4. Weights for the Total Region and 3 Farm Types

	W1 (Maximization of GM)	W2 (Minimization of risk, VAR)	W3 (Minimization of labor, TL)
Total region	0.961	-	- 0.039
Small farms	0.839	- 0.017	- 0.144
Medium farms	0.834	- 0.143	- 0.023
Large farms	0.523	-0.289	- 0.188

Table 5. Model Validation for the Total Region

	Observed values (existing production plan)	MCDM model	
		Model values	% Deviation
GM	157,747.7	188,821.0	19.7
VAR	192,800,309.8	152,797,219.4	-20.7
TL	36,148.9	40,152.0	11.1
Wheat soft	12.00	-	-100.0
Barley	1.64	-	-100.0
Maize	32.82	36.80	12.1
Alfalfa	9.59	11.50	19.9
Tobacco	7.76	8.20	5.7
Cotton	14.61	15.30	4.7
Sugar beets	2.14	2.20	2.6
Tomatoes	1.90	10.00	426.3
Wheat hard	17.54	11.20	-36.2
Set aside	-	4.80	-
Total	100.0	100.0	53.62

Table 6. Changes of Production Plan in Response to Changes in Water Prices (€/m3) in the Total Region

Crops	Variable	0.00	0.01	0.02	0.03	0.05	0.07	0.09	0.11	0.13	0.15
Wheat soft	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 beets	X71	-	-	-	-	-	-	-	-	-	-
	X72	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20
Tomatoes	X81	-	-	-	-	-	-	-	-	-	-
	X82	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Wheat hard	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

Table 7. Economic, Social and Environmental Impact on Water Price in the Total Region

Water price (€/m3)	Economic impact		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 (kg/ha)	Energy balance (10^5 kcal/ha)
0.00	2103.8	263.9	422	52.7	8	Approximately 8 months	4462.0	1324.6	200.7
0.01	1985.1	272.2	359	51.3	8	Approximately 7 months	4397.8	1332.9	205.4
0.02	1950.1	274.6	341	48.6	8	Approximately 7 months	4378.9	1335.4	205.8
0.03	1915.3	277.0	322	46.0	8	Approximately 7 months	4360.1	1337.8	206.3
0.05	1788.8	242.0	386	64.3	7	Approximately 6 months	2128.6	1136.2	128.2
0.07	1755.6	244.3	368	61.4	7	Approximately 6 months	2110.6	1138.5	128.6
0.09	1723.0	246.6	351	58.5	7	Approximately 6 months	2093.0	1140.8	129.1
0.11	1660.8	284.3	370	61.7	7	Approximately 6 months	1662.4	1175.1	136.6
0.13	1630.2	293.7	365	60.9	7	Approximately 6 months	1558.6	1183.8	138.5
0.15	1603.1	301.4	361	60.2	7	Approximately 6 months	1468.0	1191.4	140.1

Figure 1. Water Demand in the Total Region and 3 Farm Types in Relation to Water Price

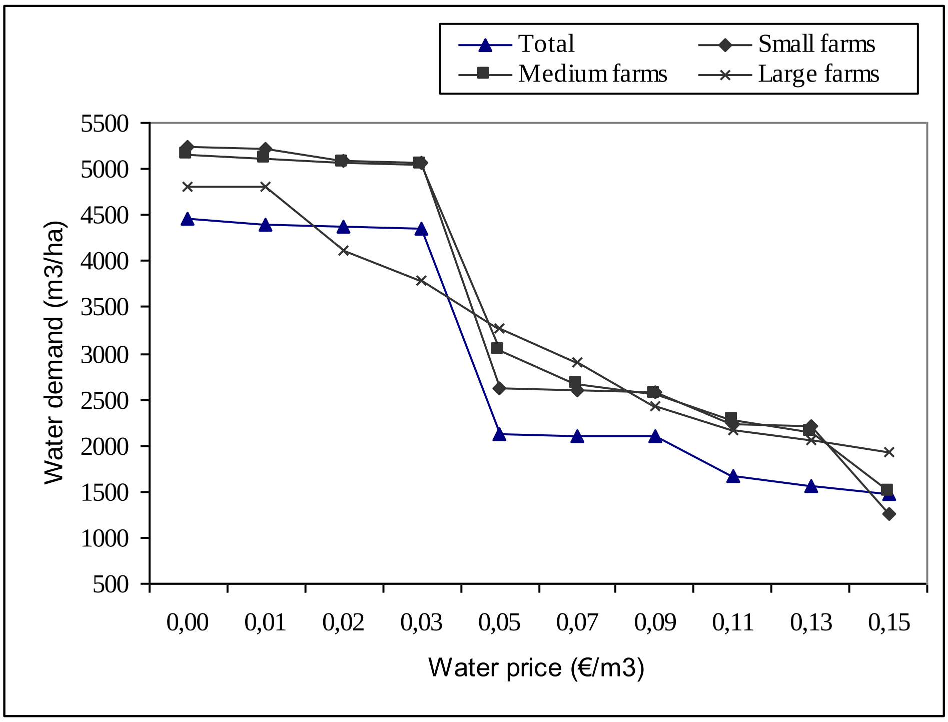

Figure 2. Farm Income in the Total Region and 3 Farm Types in Relation to Water Price

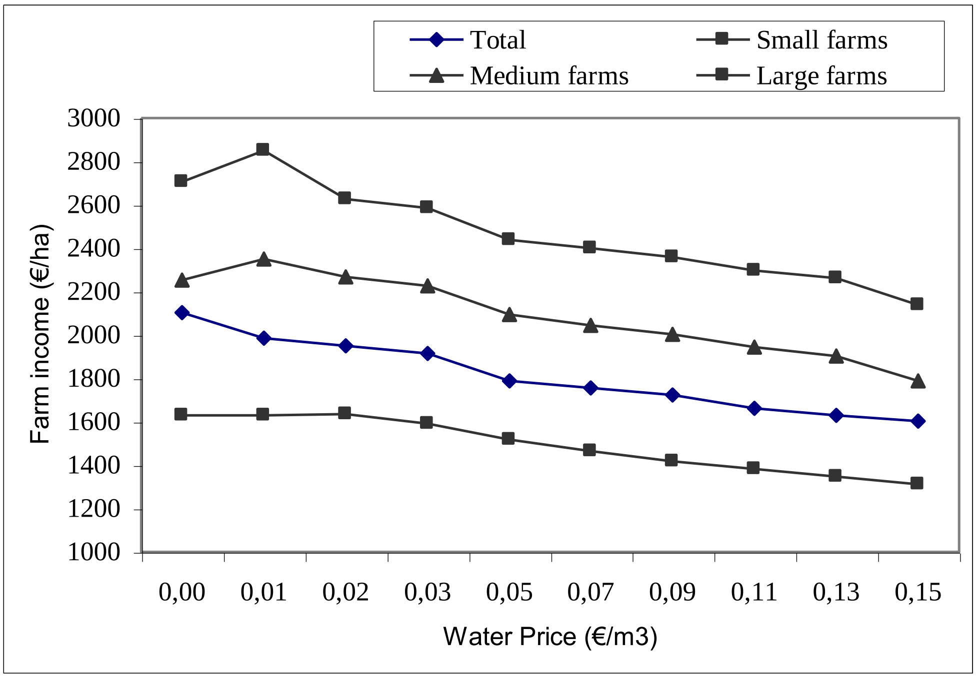

Figure 3. Labor Demand in the Total Region and 3 Farm Types in Relation to Water Price

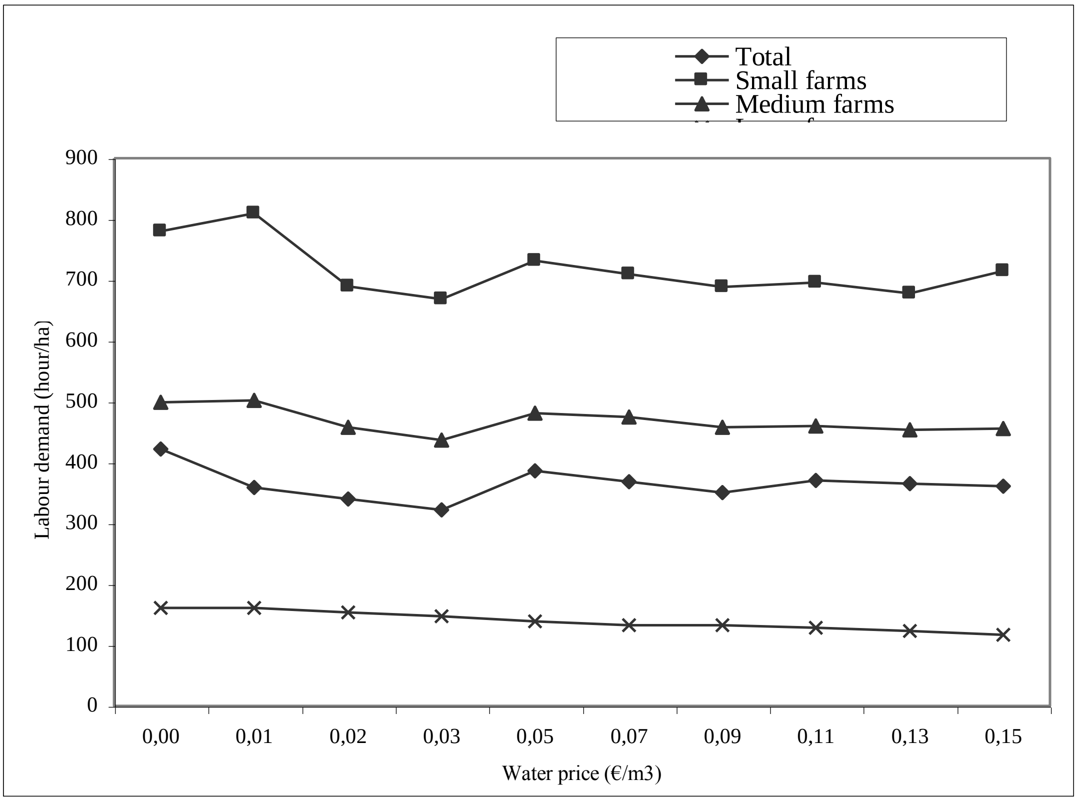

Figure 4. Fertilizers Demand in the Total Region and 3Farm Types in Relation to Water Price