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.

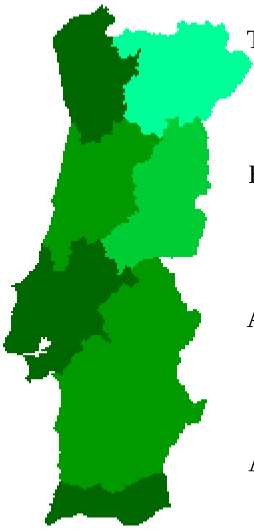
Most of the water is used in agriculture. Indeed, the use of water for irrigation purposes takes the dominant share of all uses, with 75%. When only consumptive uses are considered this share rises to 87%. Most of the water used for irrigation is pumped from surface sources, that is, directly from water courses, artificial ponds and reservoirs (INE, RGA 1989).

In general terms, the irrigated agriculture in Portugal – mainland and islands – occupies 605348 ha, that is, 15.7% of the national Usable Agricultural Area (UAA). Looking at figure 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 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 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 2. Irrigated area in each studied zone

Region	UAA (ha)	Irrigable Area (ha)	Irrigable Área (%)
Baixo Alentejo	612540	39357	6.4
Lezíria do Tejo	220209	85981	39.0
Baixo Mondego	43375	26619	61.4

(Based in INE, RGA. 1999)

Figure 2. Location of the irrigated areas.

Table 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.

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 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 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.

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 85981 irrigable hectares distributed within 7507 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 6. Identification of Lezíria do Tejo Typologies

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 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.

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 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 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[1]/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

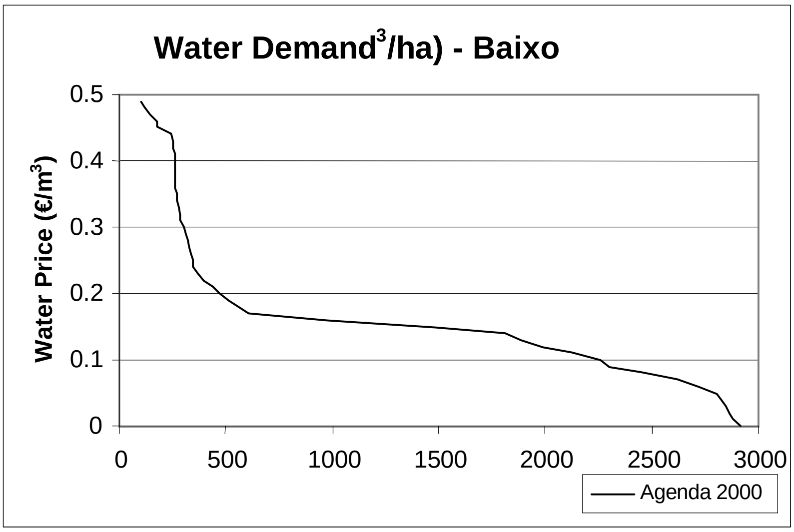
The aggregated results were obtained by weighing the respective values for the different agricultural typologies. The weights are the area occupied by each typology.

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 m3/ha, attained at a free water situation. These weighted results indicate that for water prices below 0.05 €/m3 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 €/m3, the water demand average reduction would be of 111 cubic meters per each Euro cent increase and, would even rise to 313.2 m3/0.01€ for the range of 0.14 to 0.18€/m3. At this latter price the water consumption is reduced to 555.1 m3/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.

[1] - 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.

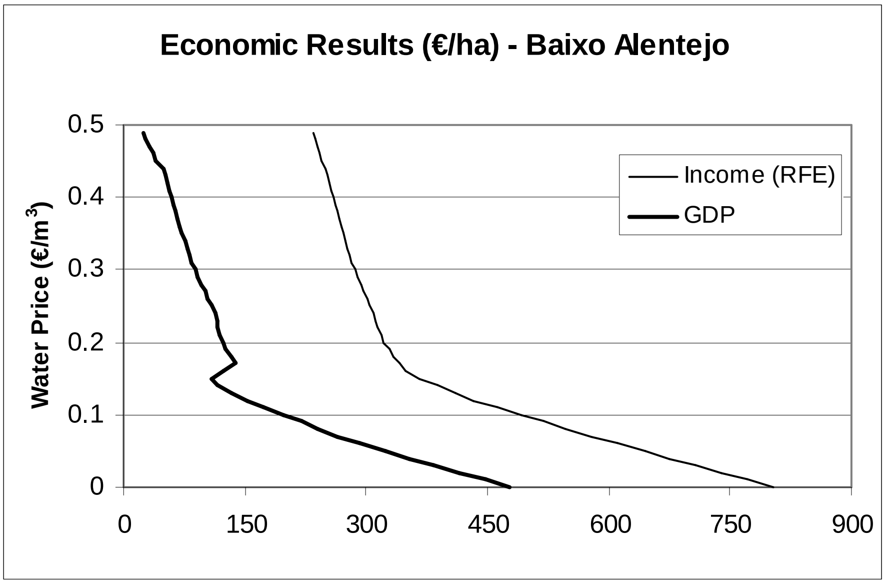
Figure 3. Aggregated Irrigation Water Demand Curve for Baixo Alentejo



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 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.

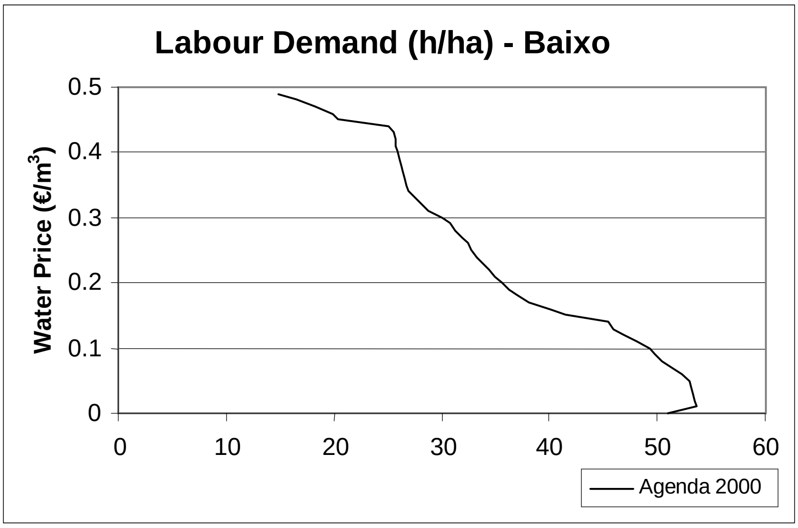
It is worthwhile to note that, especially for low water prices (below 0.10 €/m^3), the result is more an effect on farm income than on a reduction in consumption. That is to say that farmers are more likely to suffer the consequences of an increase in the water price, than to change their behavioural 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 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

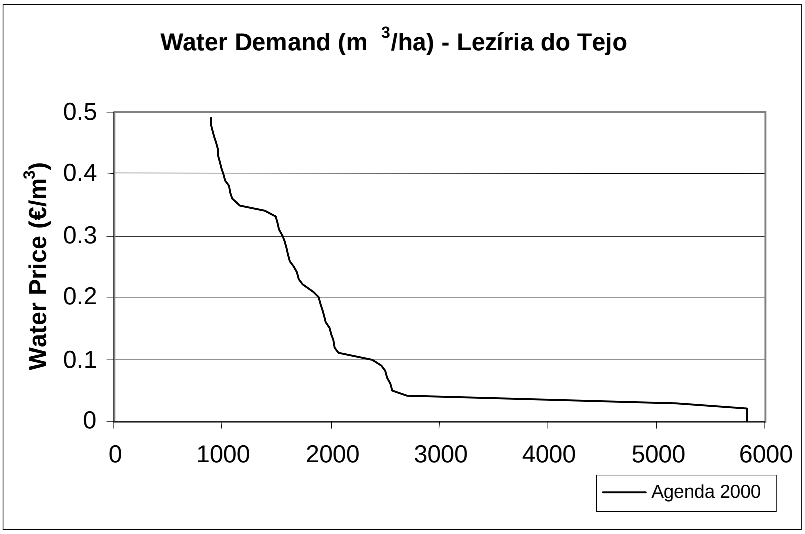
4.2.1 Water Demand (m^3/ha)

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 6. Aggregated Irrigation Water Demand Curve for Lezíria do Tejo

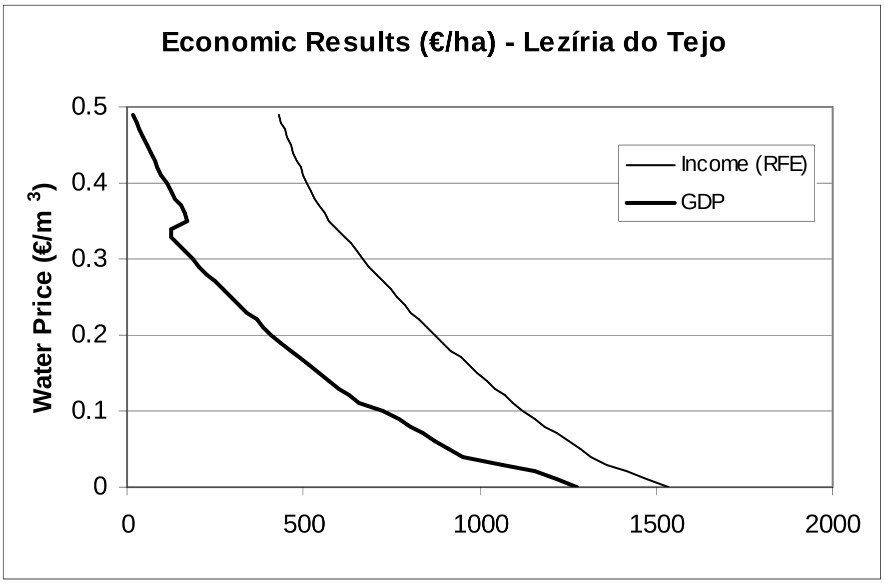


4.2.2 Economic Balance

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 7. Lezíria do Tejo Aggregated Economic Results: Income and GDP



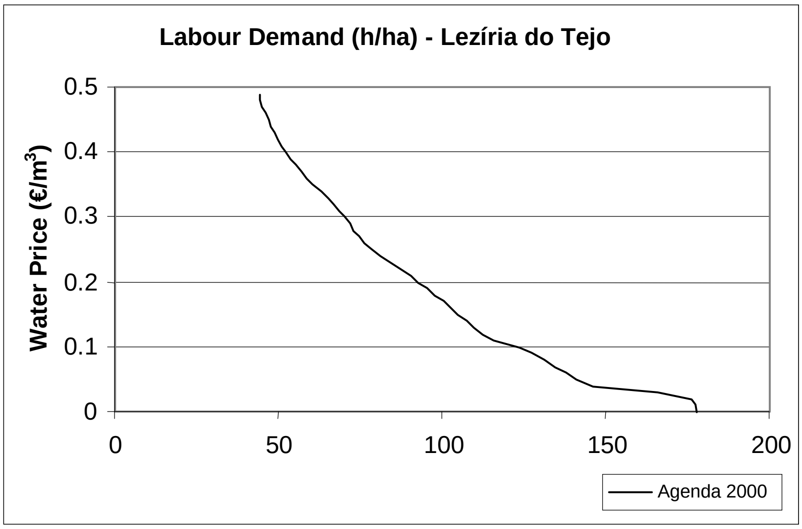
From the 0.05 €/m^3 price onwards to 0.35 €/m^3 the farm income curve is approximately equally curved, with an average loss of farm incomes of twenty four Euros per each cent increase on water prices. At the 0.35 €/m^3 level the farm income is already reduced by 960.9 €/ha to a value of 572.5 €/ha, which corresponds to a 62.7% loss.

For water prices above 0.34 €/m^3, the amount of payment for water services is higher then 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 parametrization 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 €/m3 and 0.20 €/m3, 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 €/m3 or 0.20 €/m3 would mean that the demand for labour would be reduced by one person per each 40.1 ha and 25.8 ha.

Figure 8. Aggregated Agricultural Labour Demand Curve for Lezíria do Tejo



4.2.4 Environmental Impact

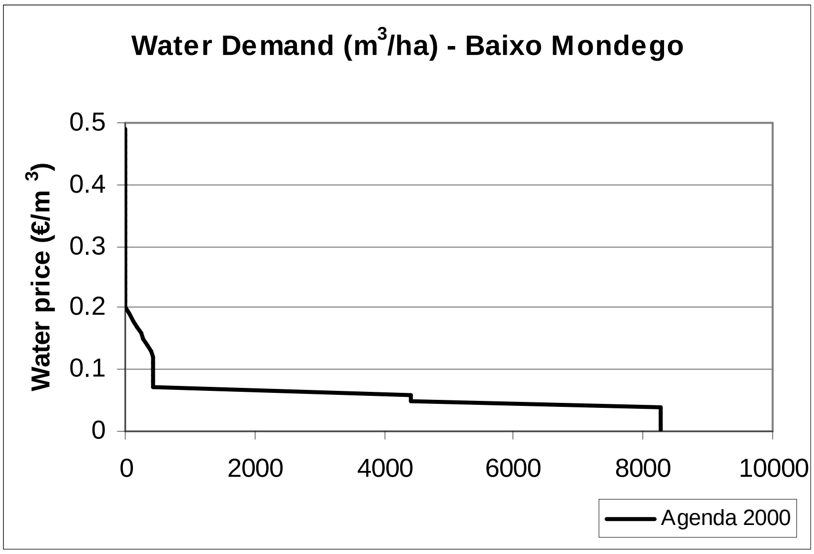
The aggregated pesticide risk indicator for this region shows a very clear decreasing tendency. From an initial value of 29315.5 it is reduced to 19171.8, for a water price of 0.10 €/m3, to 5293.0 at 0.20 €/m3, and from this price until the simulation end it is further reduced by 1766.3 units. With an 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 €/m3). For very high water prices, above 0.33 €/m3 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.

Figure 9. Aggregated Irrigation Water Demand Curve for Lezíria do Tejo

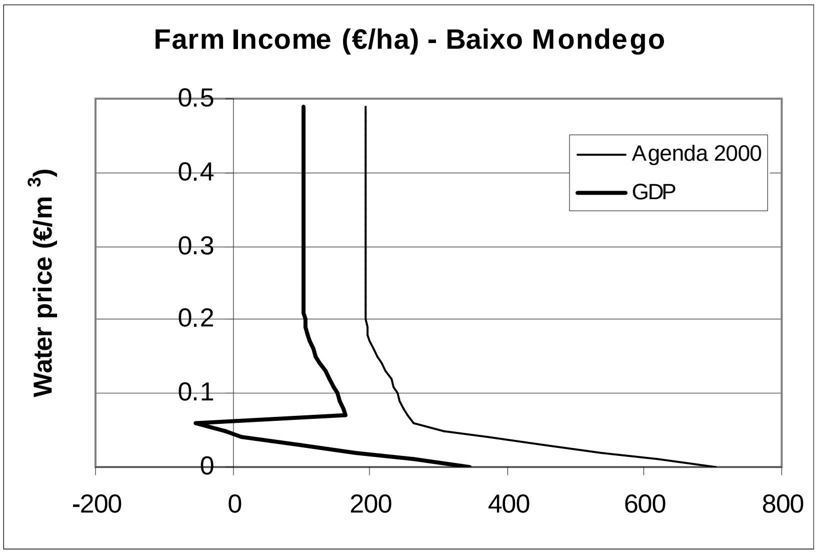


The consumption of water is 8284.0 m^3/ha at the zero water price, and stays unchanged until the water price reaches five Euro cents per cubic meter. In fact, at a price of 0.05 €/m^3 rice paddies are abandoned and the water consumption decreases by 3876.8 m^3/ha, which correspond to a reduction of 46.8% 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.

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.

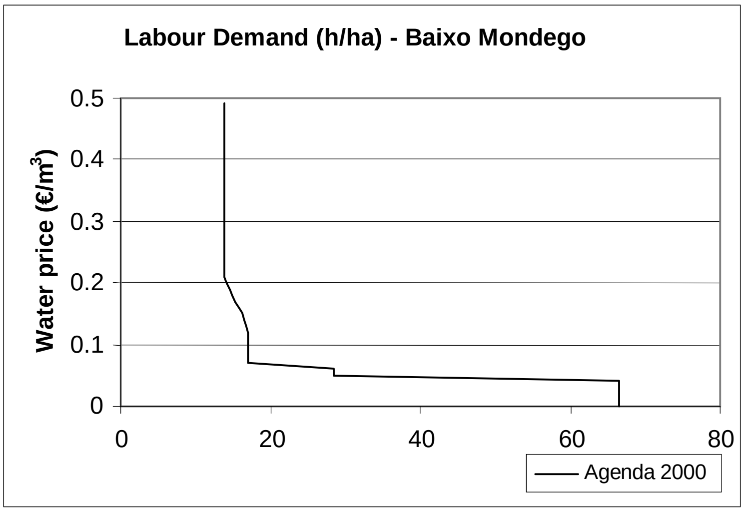
Figure 10. Baixo Mondego Aggregated Economic Results: Income and GDP



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 €/m3 the employment necessary suffers a decrease of 74.3% (that is, one full time employee less per each 45 ha).

Figure 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)

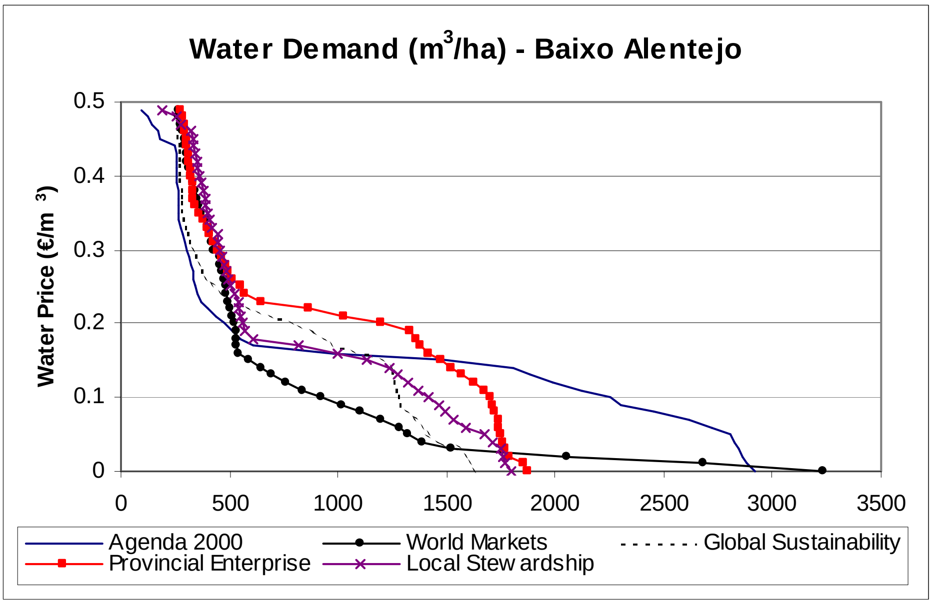
5.1 Baixo Alentejo – Agricultural Policy Scenarios

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.

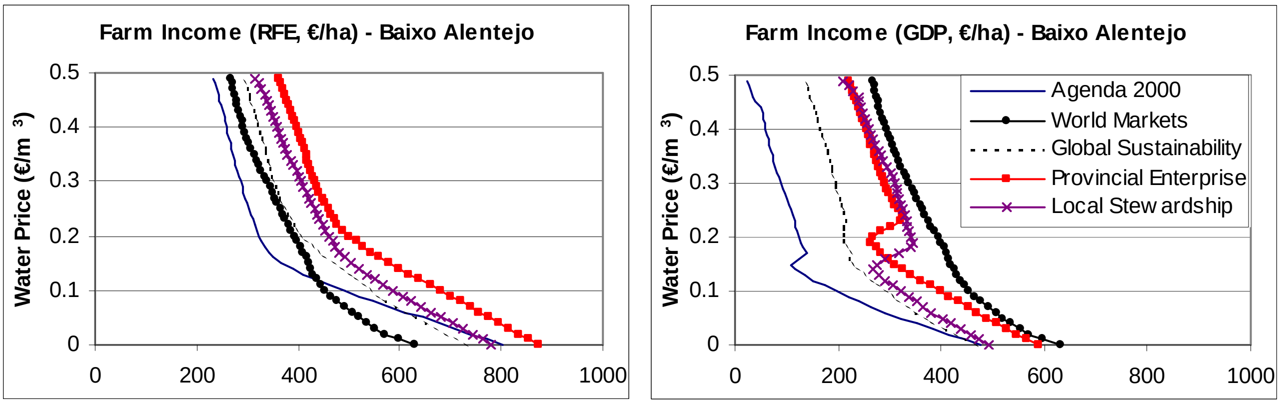
Figure 12. Aggregated Water Demand Curve for Baixo Alentejo under different Agricultural Policy Scenarios



5.1.2 Economic Balance

As far as farm income is concerned, it is possible to see (Figure 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.

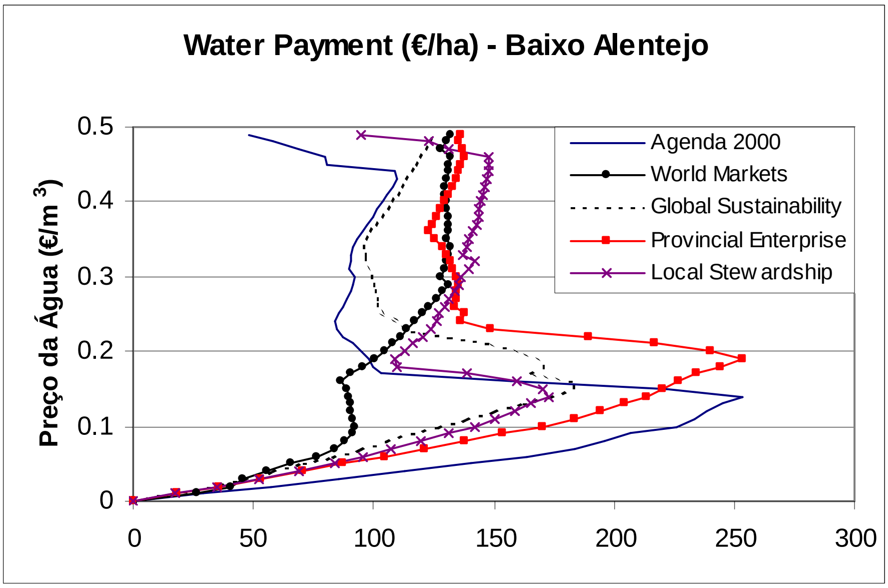
Figure 13. Aggregated Economic Results in Baixo Alentejo under different Agricultural Policy Scenarios: Income and GDP



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.

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 14. Aggregated Water Payments in Baixo Alentejo under different Agricultural Policy Scenarios

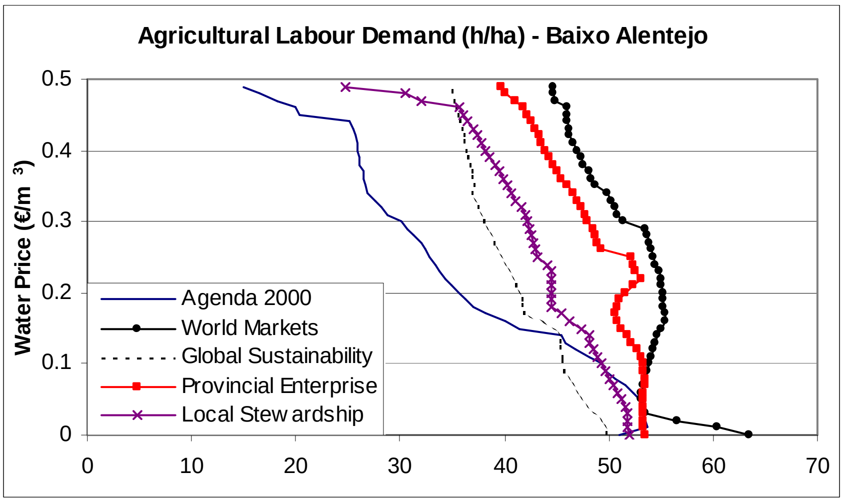


In the World Market scenario, the comparatively reduced competitiveness of most commodities in this region because of very low water prices forces the crop-mix to be changed to less water consumptive crops. In this sense it is not incorrect to say that CAP policy measures support water demanding crops.

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 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

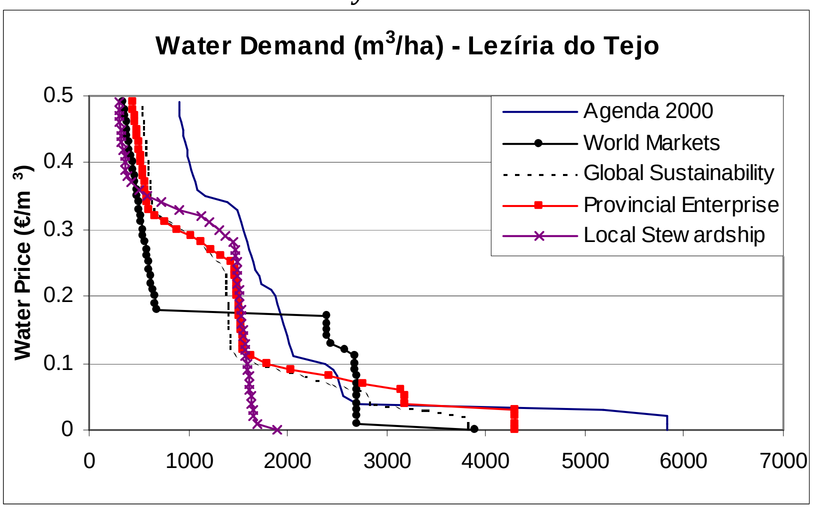
5.2.1 Water Demand (m^3/ha)

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 16. Aggregated Water Demand Curve for Lezíria do Tejo under different Agricultural Policy Scenarios

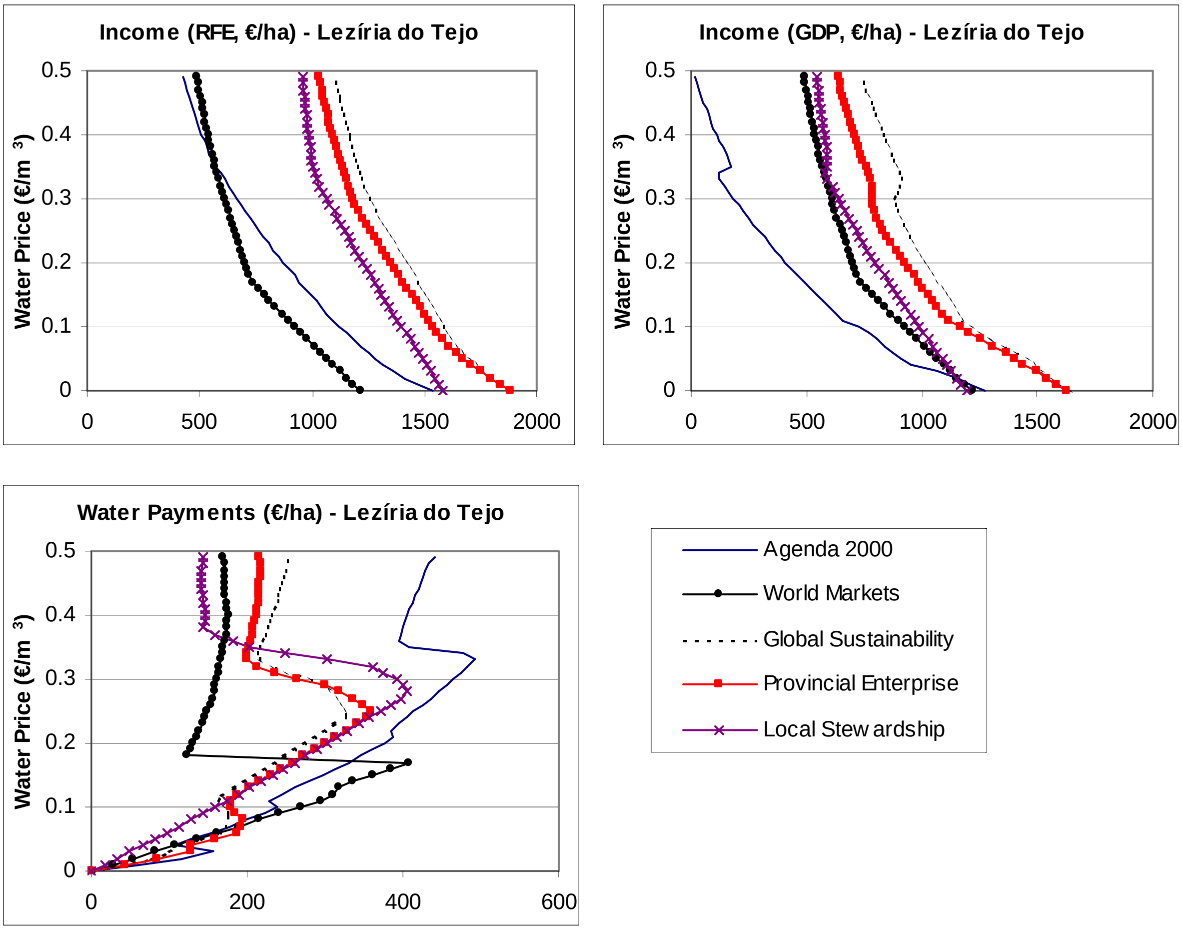


5.2.2 Economic Balance

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.

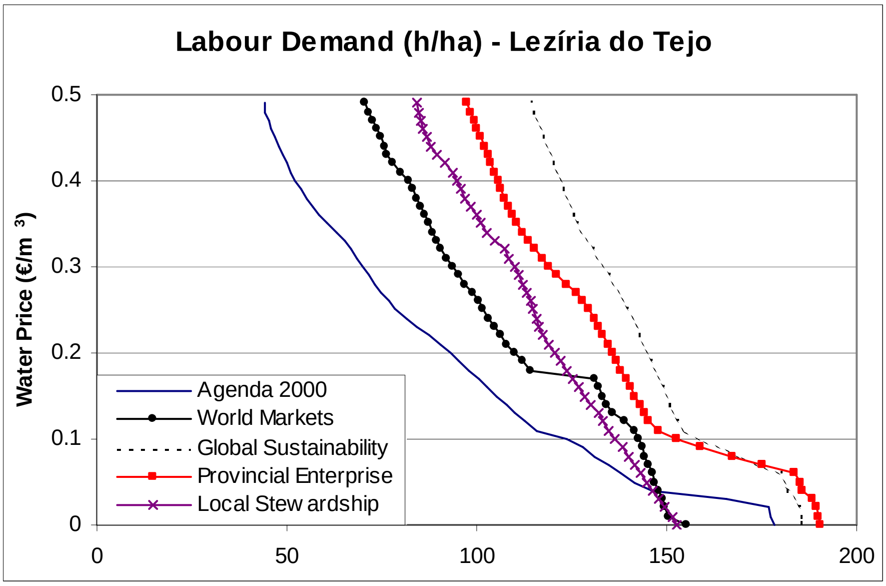
Figure 17. Aggregated Economic Results in Lezíria do Tejo under different Agricultural Policy Scenarios: Income, GDP and Water Payments



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 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.

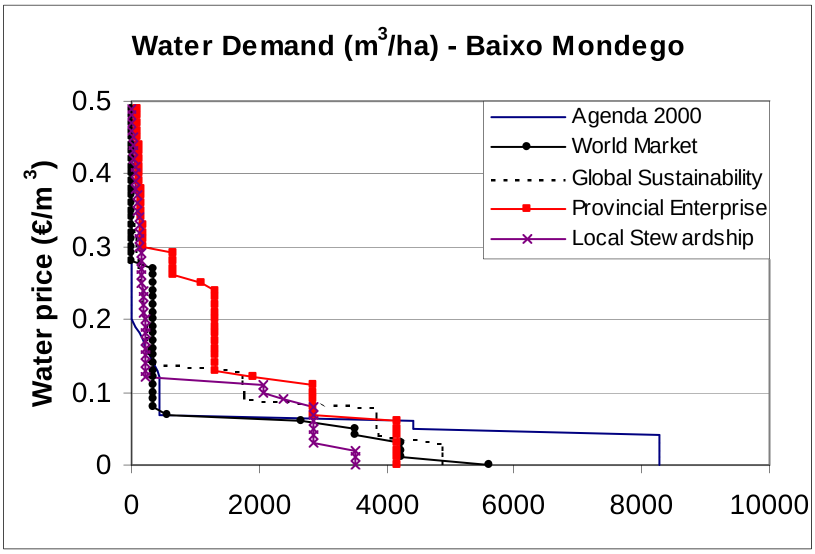
The pesticide risk indicator shows that water prices near 0.10 €/m^3 lead to very positive reductions of pesticide applications. In the case of the Local Stewardship scenario, severe reductions only occur at the water price of 0.30 €/m^3.

5.3 Baixo Mondego – Agricultural Policy Scenarios

5.3.1 Water Demand (m^3/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 19. Aggregated Water Demand Curve for Baixo Mondego under different Agricultural Policy Scenarios



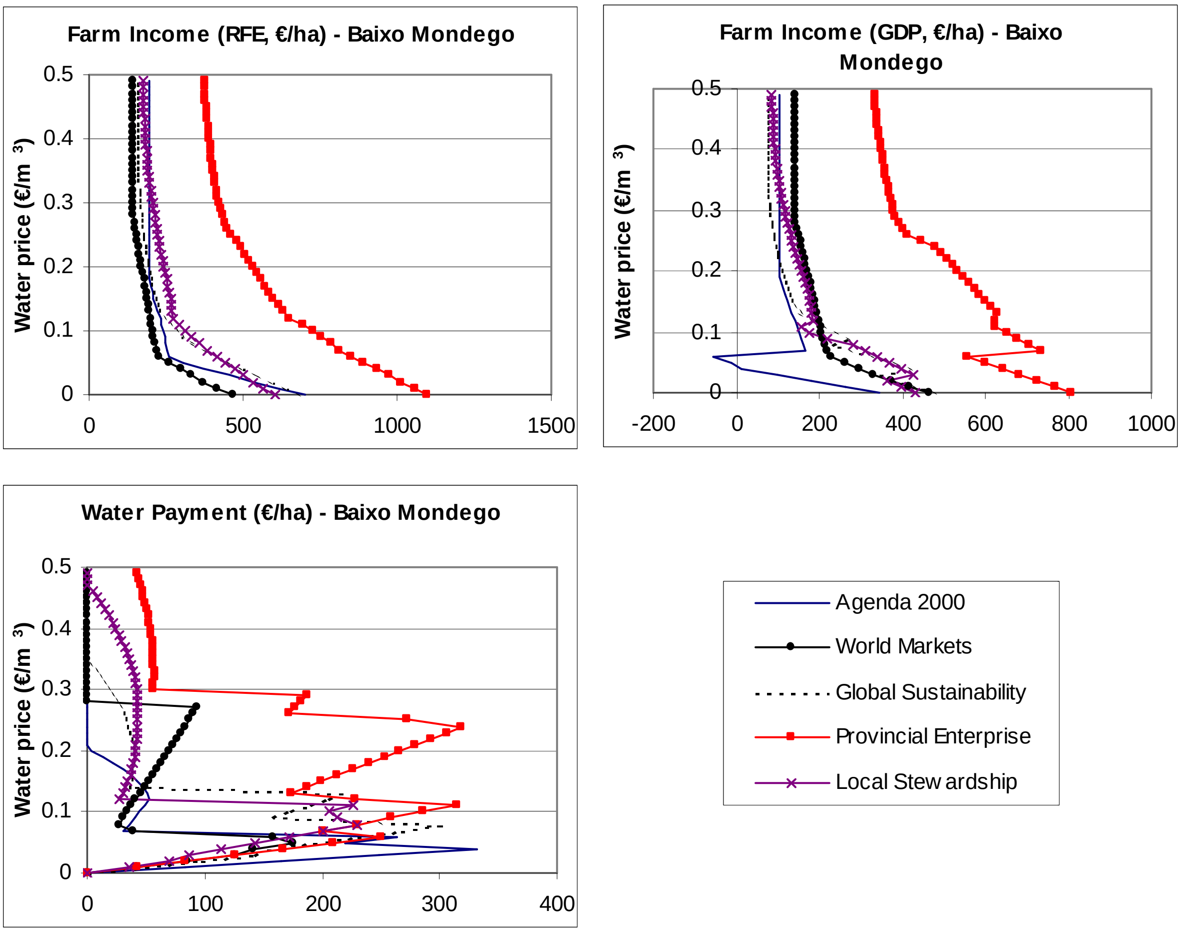
In general, it is possible to note that the capacity of resistance in Baixo Mondego to water price increases is very limited. In fact, for water prices above 0.13 €/m^3, the agricultural demand for water is reduced to negligible values. With a water price of 0.05 €/m^3 it is possible to note that the 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 €/m^3 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 Balance

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.

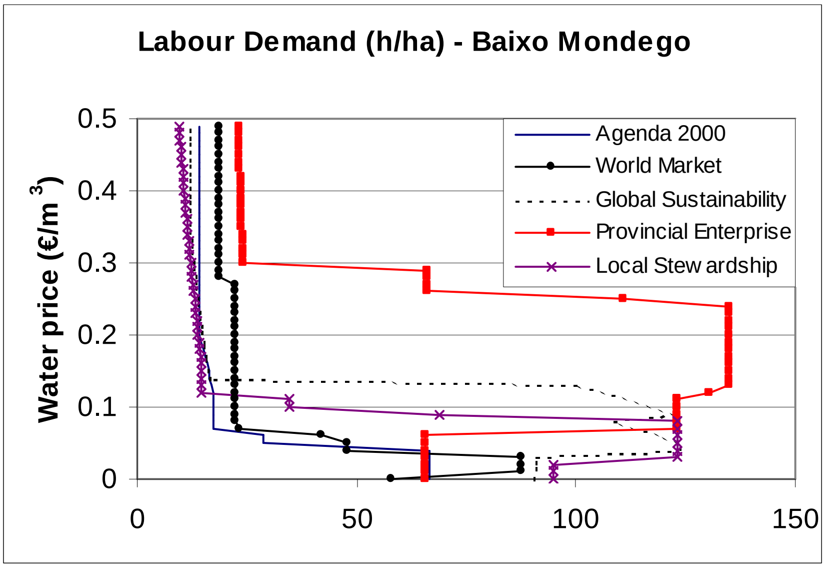
Figure 20. Aggregated Economic Results in Baixo Mondego under different Agricultural Policy Scenarios: Income, GDP and Water Payments



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 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.

7 REFERENCES CONSULTED

BAZZANI, G., PASQUALE, S., GALLERANI, V. and VIAGGI, D. (2002). "*The Sustainability of Irrigated Agricultural Systems under the Water Framework Directive: First Results*". European Association of Environmental and Resource Economics. Workshop on Policies and Tools for the Sustainable Water Management in the EU. 21-23 November, Veneza, Italy.

BOYMANNS, D. (2002). "Analysis of European Water Policy: Guidelines for Policy Scenarios". Sustainability of European Irrigated Agriculture under Water Framework Directive and Agenda 2000, internal document. European Commission. Directorate-General. Joint Research Centre. Institute for Prospective Technological Studies (Seville). Technologies for Sustainable Development.

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

EUROPEAN COMMISSION. (2000). "A Tarifação Como Modo de Reforçar a Utilização Sustentável dos Recursos Hídricos". Commission communication to the Council, to the European Parliament and to the Social and Economic Committee. COM(2000) 477 final.

GÓMEZ-LIMÓN, J. (2003). Multi-Criteria Analysis of Factor Use Level: The Case of Water for Irrigation. (to be presented at the 25th International Conference of Agricultural Economics, Durban, South Africa, 16 – 22 August, 2003).

GÓMEZ-LIMÓN, J. A. and BERBEL, J., (2000). "*Multicriteria Analysis of Derived Water Demand Functions: A Spanish Case Study*". Agricultural Systems N.º 63. pp 49-72. Elsevier Science Ltd..

GÓMEZ-LIMÓN, J. A. and RIESGO, L., (2002). "Irrigation Water Pricing: Differential Impacts on Irrigated Farms". Agadir Conference on Irrigation Water Policies: Micro and Macro Considerations. (17-19 April, 2002). Agadir. Morocco.

HUFFAKER, R. and WHITTLESEY, N. (2000). "The Allocative Efficiency and Conservation Potential of Water Laws Encouraging Investments in on-farm Irrigation Technology". Agricultural Economics, December 2000, vol, 24, n.º 1, pp. 47-60.

INE. (2001) (NACIONAL INSTITUTE OF STATISTICS). "Recenseamento Geral da Agricultura 1999: Alentejo, Principais Resultados". Theme: Agricultura, Produção Animal, Silvicultura e Pesca. Lisbon, Portugal.

MORRIS, J and VASILEIOU, K. (2003). "*Wadi Scenario Analysis: Description and Estimations*". Sustainability of European Irrigated Agriculture under Water Framework Directive and Agenda 2000, documento interno.

OECD (1999). (ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT). "The Price of Water: Trends in OECD Countries", OCDE, 1999.

ROMERO, C. and REHMAN, T. (1989). “Multiple Criteria Analysis for Agricultural Decisions”. Developments in Agricultural Economics 5. Elsevier Science Publishers. Amsterdam. Netherlands.

SARAIVA, J. and PINHEIRO, A. 2003. “*Implementação da Directiva Quadro da Água. Medidas de Política de Gestão da Procura de Água no Regadio”*. V Encontro de Economistas de Língua Portuguesa. 05-07 November, Recife, Brazil.

Sumpsi, J., Amador, M. and Romero, C. 1996. *On Farmers' Objectives: A Multi-Criteria Approach*. European Journal of Operational Research 96 (1996) 64 – 71.

TIWARI, D. and DINAR A. (2001). “Role and Use of Economic Incentives in Irrigated Agriculture”. World Bank, Irrigation papers.

TSUR, Y. and DINAR, A. (1995). “Efficiency and Equity Considerations in Pricing and Allocating Irrigation Water”. The World Bank Group. Water Resources Management. Collection Policy Research Working Paper.

UNDP (1993). (UNITED NATION PROGRAME FOR DEVELOPMENT). “Capacity Building for Sustainable Management of Water Resources and the Aquatic Environment”. Strategy Framework Document: Chapter Three. Sustainable Energy and Environment Division/UNDP. Nairoby. Kenya.

ZILBERMAN, D. and LIPPER, L. (1999). “The Economics of Water Use”. Handbook of Environmental and Resource Economics. Ed. JEROEN VAN BERGH. 1999. Edward Elgar Publishing Limited. UK.