# Planning cropping systems for the new irrigation areas under the influence of the Alqueva dam. The case study of the Odivelas irrigation scheme

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**Abstract**

This paper is about the planning of cropping systems for the new irrigation areas under the influence of the Alqueva dam. It is based on the case study of the Odivelas irrigation scheme, over the period from 1997 to 2005.

The conclusions of this study points out that the future crop alternatives for the Odivelas irrigation scheme have to be found among new crops and cropping systems that are more economically-valuable and less water consuming. Those could include low input extensive irrigated crops and high input intensive irrigated crops. The success of the expansion of irrigation schemes in the Alentejo region relies on the development of actions/policies that allow and support the development of those crops. Among these actions we can suggest the following priorities: impose limitations on water use; subsidise price of water; implement fixed land taxes; develop extension services; develop marketing and processing facilities; provide irrigation equipment and farm machinery to rent; modify land tenure legislation; reassess field size limitations and consider alternatives to improve the performance of small fields; and, reassess soil conditions such as drainage, salinity, pH and slope.

**Résumé**

*Dans ce travail, on passe en revue la planification des systèmes de culture pour des zones où l'irrigation a récemment été introduite, sous l'influence du barrage d'Alqueva. Une étude de cas est présentée concernant le périmètre irrigué d'Odivelas, dans une période comprise entre 1997 et 2005.*

*Les conclusions indiquent qu'à l'avenir, les alternatives dans le périmètre d'Odivelas doivent être cherchées parmi des cultures nouvelles et des systèmes de culture innovants, économiquement valables et garantissant des économies d'eau. Parmi les solutions possibles, on pourrait préconiser des cultures irriguées extensives et à faible apport d'intrants et des cultures irriguées à fort apport d'intrants. Le succès de l'expansion des périmètres irrigués dans la région de l'Alentejo réside dans la mise en oeuvre d'actions/politiques permettant et soutenant le développement de ces cultures. A ce sujet, il est bon de souligner les priorités suivantes : imposer des limites sur l'utilisation de l'eau ; subventionner le prix de l'eau ; appliquer un impôt foncier fixe ; promouvoir les services de vulgarisation ; développer des structures pour la commercialisation et la transformation ; fournir les équipements pour l'irrigation et les machines agricoles à louer ; modifier la législation sur le régime foncier ; réévaluer les limitations de la taille des parcelles et considérer des alternatives pour améliorer la performance des petites parcelles. En final, il serait aussi nécessaire de réévaluer les conditions du sol telles le drainage, la salinité, le pH et la pente.*

## Introduction

Odivelas is a small irrigation scheme, with about 15.000 hectares, in the South of Portugal (NUTS II, Alentejo region) that will be increased by new 12.000 irrigated hectares as a consequence of the Alqueva dam, a large European project still under construction in the region of Baixo Alentejo. Alqueva is a multipurpose project based on the construction of a dam on the Guadiana river. This dam will permit to explore the biggest water lake in Europe (250 km$^2$), for irrigated agriculture (110.000 hectares), energy production, leisure and tourism activities.

This paper is based on the information of a previous study conduced by Coelho et. al. (1998) and is organised around three basic and important questions related to the planning of agricultural production systems for the new irrigation areas under the influence of the Alqueva dam. These three questions are:

1. What crops may be cultivated under the ecological and structural conditions and limitations of the considered area?
2. What are the levels of water requirements and the economic thresholds (in face of different time and price of water scenarios) of the possible crops?
3. What is the economic viability, in the 2005 year scenario, of the possible crops and the production systems, integrated by them?

The answer to these questions is searched inside the particular environment (climate and soils) observed in the areas dominated by the Alqueva dam.

## 1. What crops may be cultivated under the ecological and structural conditions and limitations of the considered area?

With climate and soil regional data (Meteorological Station of Beja and Rainfall Station of Ferreira do Alentejo), we have run the Ecocrop, FAO model (FAO, 1983; FAO, 1985), for the selection of the crops well adapted to the climate and soil conditions of the region. Once we had no climate variation inside the Odivelas region, the climate factors and the characteristics used in the model parameterisation are constant, and express a Csa climate type of Köppen Classification.

The soil was then the only factor of expression of the

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ecological variability inside the region. The soil parameters used were: the pH; the soil texture; and the soil effective depth. Table 1 shows the characteristics defined and used in the model running. It is to note that the soil effective depth is classified in three categories, according to the model specifications: shallow - soil depth lower than 50 cm; medium - soil depth between 50 and 150 cm; deep - soil depth greater than 150 cm. We may argue that this category criterion, defined by the model developers, is too large for the type of soils that exist in the region, but we have respected it.

Table 1. *Soil parameters required for the use of the* Ecocrop *model*

| Soil Family | pH | Texture | Depth |
|---|---|---|---|
| Cambisols | 5.5 | L | S |
| Dystric Luvisols | 6.0 | L | S |
| Calcic Luvisols | 6.5 | M | M |
| Vertisols | 7.5 | H | D |
| Fluvisols | 8.0 | H | M |
| Calcisols | 8.0 | M | M |

H - Heavy; M - Medium; L - Light; D - Deep; S – Shallow

The crop selection was conducted in a step-by-step procedure, starting from a database including 1200 crops (Ecocrop data base). The process had involved the following 5 steps:

1) Köppen Climate: elimination of all the species not adapted to the Csa Köppen climate type (mesothermic, with at least one month with medium air temperature greater than 10°C, colder month with medium air temperature between 0°C and 17°C, warmer month with medium air temperature greater than 20°C, and rainfall concentrated in the cold year season);

2) Soils: elimination of all the species, the soil requirements are not satisfied by any of the soils considered;

3) Forest and spontaneous weed species: elimination of all forest species and of all herbaceous species that, according to the Ecocrop specifications, have no agronomic interest;

4) Water Regime: elimination of the species with a strong desert or mountain water regime;

5) Plant life cycle (thermal regime): elimination of the species with a minimum life crop cycle duration higher than any continuous year period inside which the lower minimum temperature registered is higher than the value of the critical low temperature requirement of the crop (variable with the life stadium of the plant).

Table 2 shows the number of crop species selected in the end of each step.

The obtained results have to be seen with caution because the criteria that have been used are very exigent and particularly not well adapted to perennial species. In respect to the climatic factors we may say that all the species selected are well adapted to local weather conditions. However an intra-species study (varieties) should be recommended for some crops.

In general terms, the conclusions of this selection process are very predictable. In the acid and light soils we found a great percentage of forages among the possible crops; in the neutral pH and heavy soils we found the usual non irrigated regional crops (wheat, barley, oats, triticale and sunflower); and in the deep soils we also found tree species, although many are rejected by the presence of drainage problems.

Table 2. *Number of crop species selected in the end of each step*

| Tested Conditions | Number of species selected |
|---|---|
| (Beginning) | 1200 |
| Step 1 - Köppen Climate | 577 |
| Step 2 - Soils | 396 |
| Step 3 - Forest and spontaneous weed species | 310 |
| Step 4 - Water Regime | 297 |
| Step 5 - Plant life cycle | 250 |

From the agro-ecological selection, that we have described, a total of 250 species have been identified as possible crops to be grown in the region. From those, taking into consideration other aspects related to the social (age, education), cultural (agricultural system traditions), structural (farm size and fragmentation) and economic (prices and markets) conditions prevailing in the region, we have retained, for subsequent analysis, the crops listed in Table 3.

The criteria that have been used in the selection of these crops are indeed subjective. Nevertheless they were conform to the specific restrictions prevailing in the re-

Table 3. *Possible and representative crops selected*

| System | Group | Crop | Crop use |
|---|---|---|---|
| Non irrigated | Cereals | Wheat (soft) | Industry |
| | | Wheat (dwarf) | Industry |
| | | Oat | Industry |
| | | Barley | Industry |
| | | Triticale | Industry |
| | Forages/silages | Ryegrass | Hay/Silage |
| | | Oat + comm. vetch | Hay |
| | Others | Sunflower | Industry |
| Irrigated | Cereals/ grain | Maize | Industry |
| | | Wheat (soft) | Industry |
| | | Wheat (dwarf) | Industry |
| | Forages/silages | Sorghum | Silage |
| | | Maize | Silage |
| | Horticultural | Lettuce | Fresh consumption |
| | | Potato | Fresh consumption |
| | | Potato | Industry |
| | | Onion | Fresh consumption |
| | | Broccoli | Fresh consumption |
| | | Melon | Fresh consumption |
| | | Green pepper | Fresh consumption |
| | | Tomato | Industry |
| | Others | Sugar beet | Industry |
| | | Sunflower | Industry |
| | Perennial trees | Olive tree | Industry |

Table 4. *Crop month and total water irrigation requirements (mm)*

| Irrigated crops | OCT | ... | APR | MAY | JUN | JUL | AUG | SEP | Total |
|---|---|---|---|---|---|---|---|---|---|
| Lettuce | | | 11.9 | 79.0 | 29.8 | | | | 120.7 |
| Potato fresh consumption | | | 41.8 | 116.4 | | | | | 158.2 |
| Sugar beet | 10.0 | | 79.3 | 92.1 | | | | | 181.4 |
| Onion | | | 51.8 | 72.3 | 144.5 | 137.5 | | | 406.1 |
| Broccoli | 10.0 | 30.0 | | | | | | | 40.0 |
| Sunflower | | | | 118.4 | 166.1 | | | | 284.5 |
| Melon | | | 14.6 | 64.0 | 137.6 | 174.5 | | | 390.7 |
| Maize (grain) | | | | 39.7 | 133.6 | 234.2 | 147.0 | | 554.5 |
| Maize (silage) | | | | 39.7 | 133.6 | 214.2 | 212.9 | | 600.4 |
| Olive trees | | | | | | 103.9 | 93.1 | 93.1 | 290.1 |
| Green pepper | | | 14.6 | 37.2 | 143.7 | 196.7 | 181.6 | 88.6 | 662.4 |
| Sorghum (silage) | | | | 72.1 | 149.1 | 204.9 | 80.2 | | 506.3 |
| Tomato (industry) | | | 14.6 | 22.7 | 162.3 | 248.4 | 90.7 | | 538.7 |
| Wheat | | | 55.2 | 98.7 | | | | | 153.9 |

gion. From those, the most important are: the representativeness and the economic importance of the crop; and the potential of the crop maintenance or expansion that we may expect under a scenario of introduction or expansion of the agricultural irrigated area.

By these rules we have included not only the main representative crops of the non-irrigated systems (wheat, barley, oat and sunflower) and of the irrigated systems (maize, sunflower, wheat, and tomato) of the region, but also the following ones:

- Other crops that, despite their lower expression in the region, have being cultivated with success as crop alternatives to the traditional cropping system (ex. sugar beet, irrigated olive trees);
- Non irrigated and irrigated forages and silages, with the purpose of evaluating their expansion potential, assuming a better and more tied integration between the crops and animal production systems of the region;
- Horticultural crops for fresh use or industrial consumption that, despite their lower expression in the region, could become very important cash crops; due to the difficulty of the estimation of the future conditions of commercialisation of these crops (prices and markets), we have decided to study a wide range of crops including melon, broccoli, green pepper, lettuce, potato and onion.

## 2. What are the levels of water requirements and the economic thresholds (in face of different time and price of water scenarios) of the possible crops?

### 2.1. Water requirements estimate

Based on the standards of local rainfall and potential evapotranspiration, and on soil and plant parameters extracted or adapted from Doorenbos & Pruitt (1984) and Doorenbos & Kassam (1987), we have performed a water requirement estimate for each crop. The simulation was conducted with the model Isareg (Teixeira, 1994), under the assumption of an opti strategy. The results of the model performed are showed in Table 4.

Table 5 shows the real and total crop water requirement is a consequence of the soil/plant useful water capacity and the efficiency of the irrigation method. Rain-type methods include centre pivots, sprinklers and rain guns.

### 2.2. Estimation of the economic thresholds (in face of different time and price of water scenarios) of the possible crops

The economic characterization of agricultural technologies is always a very difficult task to perform, due to the great variability of the factors that are to be considered. If at the level of the inputs there are some difficulties to overcome, it is at the level of the productivities and sale prices that the problem really poses. Rain-fed crops, particularly under a Mediterranean climate like the one we have in the Odivelas and supported by a common market and policy organization like the CAP, have typically more variability in cop productivities than in product prices; we may say just the opposite for irrigated crops that don't benefit from any specific common market policy, like fresh consumption horticultural products; irrigated crops with well-known

Table 5. *Irrigation crop water requirement estimates*

| Irrigated Crop | Irrigation method | Useful water capacity (mm) | Efficiency (%) | Real water requirement ($m^3$/ ha) |
|---|---|---|---|---|
| Lettuce | Drip irrigation | 120.7 | 90 | 1341 |
| Potato fresh consumption | Rain-type | 158.2 | 70 | 2260 |
| Sugar beet | Rain-type | 181.4 | 70 | 2591 |
| Onion | Rain-type | 406.1 | 70 | 5801 |
| Broccoli | Rain-type | 40.0 | 70 | 571 |
| Sunflower | Rain-type | 284.5 | 70 | 4064 |
| Melon | Drip irrigation | 390.7 | 90 | 4341 |
| Maize corn | Rain-type | 554.5 | 70 | 7921 |
| Maize silage | Rain-type | 600.4 | 70 | 8577 |
| Olive trees | Drip irrigation | 290.1 | 90 | 3223 |
| Green pepper | Drip irrigation | 662.4 | 90 | 7360 |
| Sorghum silage | Rain-type | 506.3 | 70 | 7233 |
| Processing tomato | Drip irrigation | 538.7 | 90 | 5986 |
| Wheat | Rain-type | 153.9 | 70 | 2199 |

Table 6. *Productivity and price assumptions considered in the construction of the 1997 and 2005 scenarios*

| Technology | | 1997 | | | 2005 | |
|---|---|---|---|---|---|---|
| | Produtiv. (kg) | Product price (esc/kg) | Product subsidy (esc/kg) | Area subsidy (esc/ha) | Product price (esc/kg) | Compensatory aid (esc/ha) |
| Lettuce drip irrigation | 22000 | 60.0 | | | 60.0 | |
| Oat | 1600 | 28.6 | | 29600 | 20.9 | 29600 |
| Oat + comm. vetch | 5200 | 17.0 | | | 13.6 | |
| Ryegrass silage | 32000 | 7.0 | | | 5.6 | |
| Potato fresh consumption rain irrigation system | 35000 | 22.0 | | | 22.0 | |
| Sugar beet rain irrigation system | 50000 | 9.8 | | 24000 | 8.2 | |
| Onion rain irrigation system | 24000 | 40.0 | | | 40.0 | |
| Rainfed barley | 1900 | 27.2 | 9.4 | 29600 | 16.9 | 29600 |
| Broccoli rain irrigation system | 13000 | 49.0 | | | 49.0 | |
| Sunflower rain irrigation system | 1800 | 43.9 | | 109500 | 43.8 | 109500 |
| Rainfed sunflower | 600 | 43.9 | | 51900 | 43.8 | 51900 |
| Melon drip irrigation | 14500 | 50.0 | | | 50.0 | |
| Maize corn rain irrigation system | 11000 | 27.3 | 7.4 | 85000 | 20.3 | 85000 |
| Maize silage rain irrigation system | 60000 | 7.0 | | | 5.6 | |
| Olive trees drip irrigation | 2700 | 80.0 | | | 78.0 | |
| Green pepper drip irrigation | 35000 | 35.0 | | | 35.0 | |
| Sorghum silage rain irrigation system | 75000 | 6.0 | | | 4.8 | |
| Processing tomato drip irrigation | 70000 | 18.6 | | | 15.7 | |
| Soft wheat rain irrigation system | 5000 | 29.8 | 14.9 | 49200 | 24.3 | 49200 |
| Rainfed soft wheat | 2100 | 29.8 | 14.9 | 29600 | 24.3 | 29600 |
| Dwarf wheat rain irrigation system | 4500 | 39.9 | | 120300 | 32.7 | 120300 |
| Rainfed dwarf wheat | 2000 | 39.9 | | 101200 | 32.7 | 101200 |
| Rainfed triticale | 1700 | 27.6 | 9.4 | 29600 | 22.0 | 29600 |

sales prices, like those produced for industrial use (potato, tomato, wheat, barley,…), are obviously the easiest and the most accurate to study in economic terms.

One way or another, the study of the representative crop economic accounts of one region is always a long and hard task. The study which this work is based on, had followed a few and clear assumptions that are important to remember:

– use of price products and factors scenarios for the 1997 and 2005 years;

– all the machines (except irrigation ones) and respective operators' time requirements are considered to be rented, so the machinery plus operator cost is considered to be equal to the renting price;

– the operation times are considered to be equal to the execution ones;

– the base price of water for irrigation was considered to be equal to 10 escudos/m$^3$, as this is the usual price collected in other irrigation schemes of Alentejo, where the water is distributed under pressure[1];

– costs of irrigation equipment were considered separately;

– the crop productivities were defined in a subjective manner, taking into account the values declared by the farmers and discussed with technicians and farm products clients;

– cereals, sunflower and sugar beet prices include all product and area CAP subsidies;

– prices for horticultural products were indicated by usual industrial clients or derived from the study of large market month prices series.

Table 6 shows the productivity and price assumptions considered in the construction of the 1997 and 2005 scenarios.

Given the above-described assumptions, it is to notice that the economic results presented in Table 7 aren't exactly gross margins as they take into account some fixed costs related to the amortization of the irrigation equipment. From the analysis of those economic results, we can conclude:

– for the considered conditions, namely the water price of 10 escudos/m$^3$, and excluding the cases of the sunflower and the olive trees, the irrigated crops always have higher margins than the rainfed crops;

– excluding the wharf wheat, all the other rainfed crops have margins lower than 50000 escudos/ha;

– excluding the cases of the sunflower and the olive trees, all the other irrigated crops have margins higher than 80000 escudos/ha. However it is to notice that the productivity considered for those two crops (sunflower and olive trees) are lower than it could be expected from the technology supposed (olive trees could easily reach 4000 kg/ha and sunflower 2500 kg/ha);

– excluding the wharf wheat, all the other generally selected crops possibly cultivable in all the scheme (soft wheat, triticale and sunflower) have margins under 35 contos/ha;

– in the first scenario (1997) there are several irrigated crops that could be very widely cultivated, considering the ecological and technical restrictions, in the scheme, and that simultaneously generate high economic returns; the more expressive examples include sugar beet (that could be cultivated in 45.1% of the scheme area and that has an economic margin of 197 contos/ha), processing tomato (54.6% of the area; 675000 escudos/ha), dwarf wheat (54.9% of he area; 103000 escudos/ha), sorghum for silage (70.4% of the area; 112000 escudos/ha), maize for corn (70.7% of the area; 160000 escudos/ha) and maize for silage (70.7% of

[1] 1 euro = 200,482 escudos; 103 escudos ª 5 euros

Table 7. *Economic margins estimated for the different technologies in the context of 2005 and 1997 scenarios*

| Technology | Margin 1997 (escudos/ha) | Margin 2005 (escudos/ha) | Var. 2005/1997 (escudos/ha) | Var. 2005/1997 (%) |
|---|---|---|---|---|
| Rainfed wheat soft | 29756 | -1513 | -31269 | -5 |
| Rainfed barley | 30423 | 1800 | -28623 | 6 |
| Soft wheat rain irrigation system | 89544 | 5912 | -83632 | 7 |
| Rainfed triticale | 22585 | 6011 | -16574 | 27 |
| Oat + Comm. vetch hay rainfed | 17833 | 7530 | -10303 | 42 |
| Rainfed oat | 14031 | 9435 | -4596 | 67 |
| Rye grass silage | 43589 | 18380 | -25209 | 42 |
| Olive trees drip irrigation | 17970 | 22548 | 4578 | 125 |
| Maize corn rain irrigation system | 160218 | 27334 | -132884 | 17 |
| Maize silage rain irrigation system | 85753 | 28666 | -57087 | 33 |
| Sunflower rain irrigation system | 24231 | 36001 | 11770 | 149 |
| Rainfed Sunflower | 31865 | 36409 | 4544 | 114 |
| Sorghum silage rain irrigation system | 111522 | 49590 | -61932 | 44 |
| Rainfed dwarf wheat | 87286 | 84457 | -2829 | 97 |
| Wheat dwarf rain irrigation system | 116694 | 102662 | -14032 | 88 |
| Sugar beet rain irrigation system | 197031 | 121760 | -75271 | 62 |
| Melon drip irrigation | 154822 | 184327 | 29505 | 119 |
| Broccoli rain irrigation system | 230348 | 267891 | 37543 | 116 |
| Onion rain irrigation system | 220355 | 302716 | 82361 | 137 |
| Lettuce drip irrigation | 315628 | 338076 | 22448 | 107 |
| Green pepper drip irrigation | 379034 | 427036 | 48002 | 113 |
| Potato fresh consumption rain irrigation system | 421872 | 457192 | 35320 | 108 |
| Processing tomato drip irrigation | 675171 | 537842 | -137329 | 80 |

the area; 86000 escudos/ha).

The obtained results, in the context of the 1997 scenario, clearly point out the economic advantage of the irrigated versus the rainfed crops. However, we should notice that this economic advantage is of course very dependent on the water price level. The price that we have used (10 escudos/m³) could be, by comparison with other Alentejo schemes, considered as a low one. On the other way, as we have discussed before, the perspectives of evolutions of the economic margins of many of the crops considered, namely the traditional ones (wheat, barley, triticale and sunflower), are not favourable. It is then prudent and necessary to carefully study those two aspects, in order to set the economic crop productivity thresholds as a function of water and product prices.

The crop accounts used in the 2005 scenario are, in respect to the technical itineraries, the same that were built for the 1997 scenario. This means that we have adopted a conservative view of the farm innovation adoption process in the area, given the time horizon of 1997-2005; as a consequence, the productivities of the crops do not change. This in fact is a to pessimistic perspective, as the recent local history of some cops, like the processing tomato, shows remarkable crop increases, due to technology changes, like the adoption of drip irrigation systems. This limitation however brings up a direct comparison of the crop margins achieved in 1997 and 2005 knowing that the differences are explained exclusively by changes in the economic factors (prices and CAP support measures).

In real terms, and for the period 1997-2005, we have considered the following economic changes:

– a 5% increase in labour costs;

– a 12% decrease in machine and equipment acquisition costs;

– a 14% decrease in the cost of intermediate inputs, except in water cost that remains constant at the level of 10 esc/m³.

Changes in product subsidies and prices, perspective under the CAP environment, were considered crop by crop. The already mentioned Table 6 resumes all this information.

By means of Table 7, already mentioned before, we can compare the economic results estimated for the crops in the 1997 and 2005 scenarios.

In the transition from the 1997 scenario to the 2005 scenario, it is to notice that the economic results of the cereal crops suffer a drastic reduction, being the dwarf wheat the only exception. In fact in the year 2005, only three rainfed crops, from the eight selected and possible ones, possess economic margins greater than 10000 escudos/ha: ryegrass for silage; sunflower and dwarf wheat. The obtained results clearly put in question the economic viability of other rainfed crops (soft wheat, barley, triticale, oat, oat+ comm. vetch, ryegrass for hay), if we keep in mind that the margins should be enough to cover, among other non considered costs, the land rent and the management work.

On the other side, none of the tree crops with returns over than 10 contos/ha constitutes, necessarily, a viable alternative. The expansion of the ryegrass silage crop, besides its low margin, depends on the development of the animal production farming systems. Actually only a small percentage of the farmers produce animals (26%) being these, in the majority of the cases, beef and sheep in extensive regimes, that doesn't justify the ryegrass price implicit in the crop budget. Sunflower is maybe the most credible alternative in the rainfed crops. However, the compensatory subsidy given to the crop (52 cantos/ha), on which the economic viability of the crop largely depends, is under a great pressure, due to the production penalties directly tied to the quota regime. Dwarf wheat is the most interesting crop, given its margin of 85 contos/ha, but is also the more restricted crop in terms of growth potential given the small amount of quota attributed to Portugal.

Many of the traditional irrigated crops (maize, sunflower, olive trees) also seem to be not great alternatives to the rainfed crops. Those crops have indeed lower results than the

Figure 1. *Sensibility analysis to the variation of the water price of the economic margins of several extensive crops under the 2005 scenario*

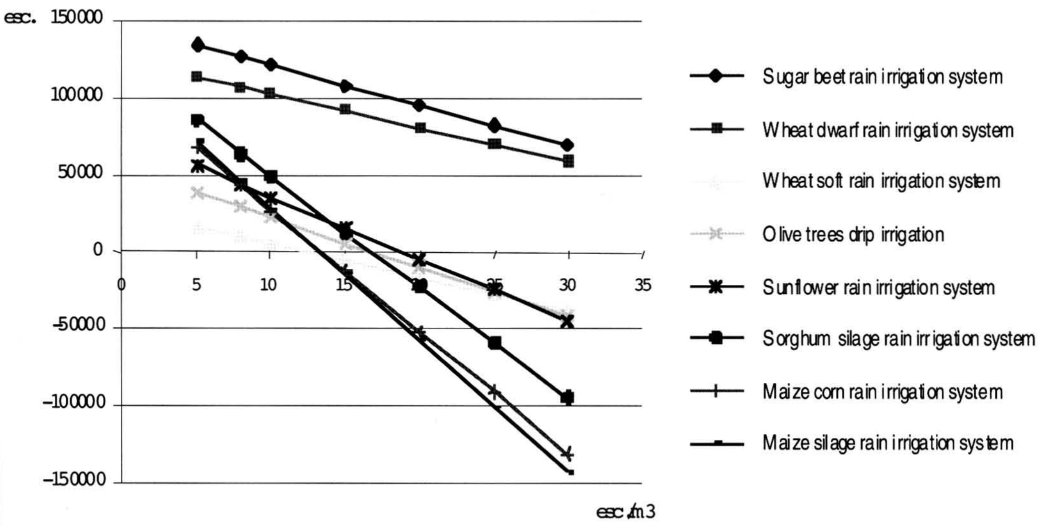
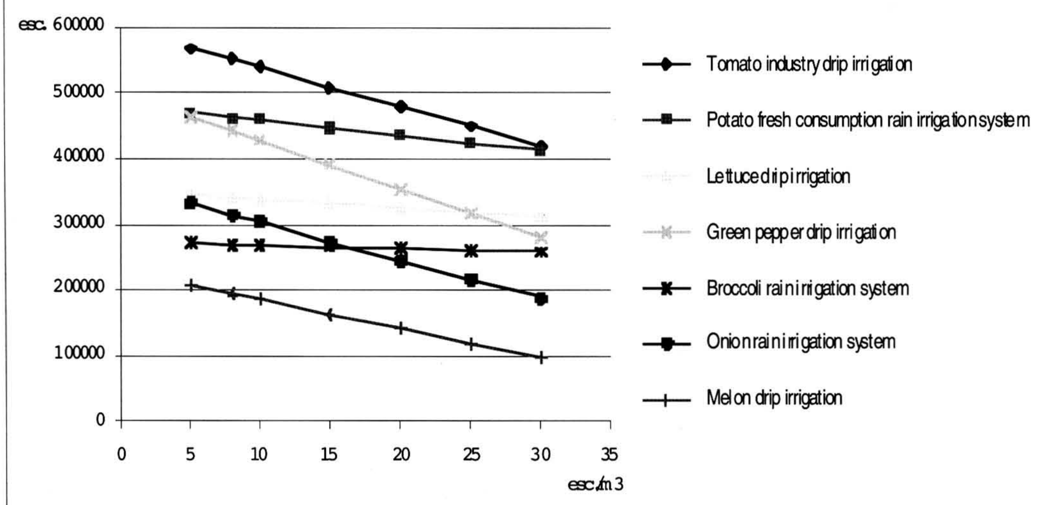



Figure 2. *Sensibility analysis to the variation of the water price of the economic margins of several horticultural crops under the 2005 scenario*




rainfed crops. In these conditions we cannot expect an enthusiastic response of the farmers to irrigation. The margin of the sorghum silage, although high, is, as in the case of the ryegrass, very dependent on the development and integration of the animal component of the systems.

Excluding these crops, we can only count, for the revival of the future irrigated areas, on dwarf wheat, sugar beet, horticultural crops (for fresh consumption or for agro-industries). All these crops have high economic margins, but dwarf wheat and sugar beet have to face tied production quotas and horticultural crops have to meet strong quality exigencies and marketing restrictions. Given this panorama, the success of the new irrigation schemes seems to be very dependent on two critical tasks: first, the renegotiation of the Portuguese quotas related to dwarf wheat, sugar beet and tomato; second, the development of an effective innovation and extension program of best management irrigation practices, that facilitate and support the transition from a rainfed agriculture to an irrigated one.

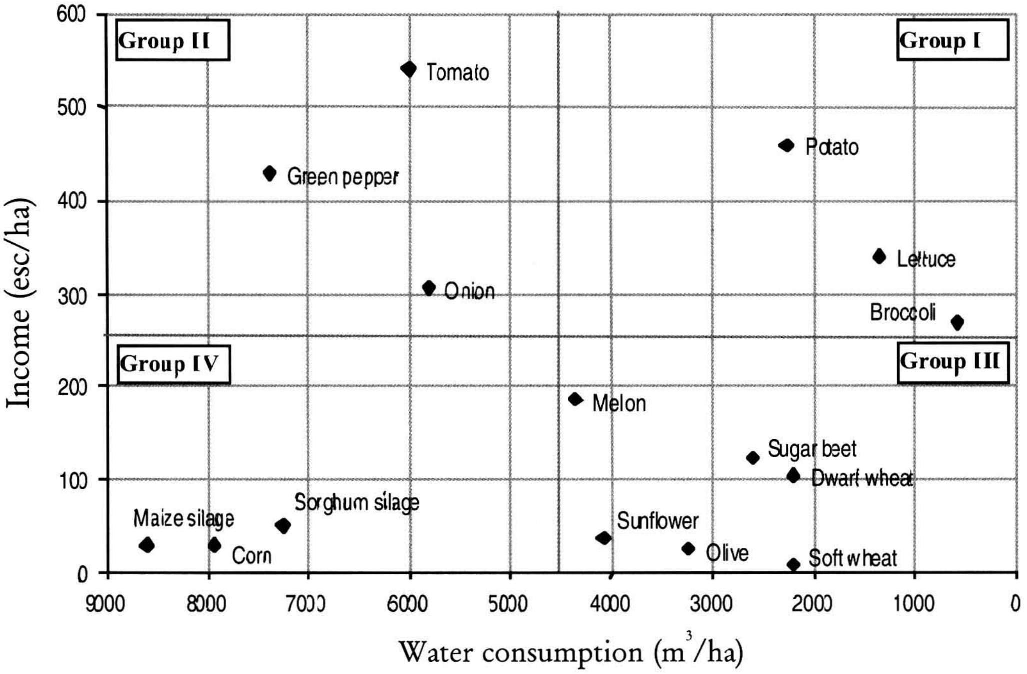
Figures 1 and 2 present the evolution of the crop margins in face of different water price scenarios, the price varying from 5 esc/m$^3$ to 35 5 esc/m$^3$. At first sight, we can conclude that negative margins start to occur at a price of 13 escudos/m$^3$ (soft wheat and maize) and that from 20 escudos/m$^3$, only dwarf wheat, sugar beet and horticultural crops are viable.

Figure 1, where large extensive crops are considered, clearly shows that between 13 escudos/m$^3$ and 20 escudos/m$^3$, almost all of the crops become non profitable. Only the dwarf wheat and the sugar beet resist. In Figure 2, where the horticultural crops are reported (for fresh consumption or agro-industry) we can see that inside the water price variation, all the crops remain profitable.

In Figure 3 we have tried to group the crops/technologies into four classes, combining their profitability and their water consumptions. If we consider the barriers of 250 contos/ha of profitability and 5000 m$^3$/ha of water consumption, it is possible to divide the crops/technologies into four groups:

- Group I - high profitable and low water consumption crops: lettuce, broccoli and potato;
- Group II - high profitable and high water consumption crops: tomato, green pepper and onion;
- Group III – medium/low profitable and low water consumption crops: melons, sugar beet, dwarf wheat;
- Group IV - medium/low profitable and high water consumption crops: maize (corn, silage) and sorghum (grain, silage).

Figure 3. *Distribution of the crop technologies by categories of economic results and water consumption under the 2005 scenario*




## 3. What is the economic viability, in the 2005 year scenario, of the possible crops and the production systems, integrated by them?

In the previous analysis, we have considered the crops one by one. However, rarely are the crops that can be cultivated individually, with success, in monoculture. Even in the cases where this practice is technologically possible, such as in the maize crop, some years later several problems become so evident – crop productivity, soil fertility and plant health problems – that put in question the sustainability of the crop/system. In the large majority of the crops, namely when the crops are very sensitive to sanitary problems (like in the tomato crop), it is necessary to respect a minimum recurrent time period of the crop (in the case of the tomato crop, a 3-4 year period is normally considered). This is the main reason to justify the need to study and analyse cropping systems, where crop rotations are proposed and evaluated under the assumptions of the 2005 scenario.

Table 8 summarizes the cropping systems proposed and their economic results. The five systems considered intend to cover a wide diversity of solutions in order to represent, in generic terms, the possible ecological, technological, market and economic system options in Alentejo and under the assumptions of the 2005 scenario. These options include, besides one rainfed and another irrigated traditional system, two innovative system proposals that could be undertaken by the development of the formers. In addition to those four, one innovative irrigated system is presented, based on horticultural crops. All the systems considered were developed under a series of constrains, from which we should notice:

- The sequence of crops were decided taking into account the basic rules of crop rotations construction, namely the minimum recurrence period of the principal or head crop of the rotation;
- The two rainfed systems presuppose the existence and the integration with an animal production component in the farm, which justifies the inclusion of some less economic attractive crop options (ryegrass or fallow);
- The irrigated systems don't include any rainfed crops, even when these are economically attractive;
- We have decided to pursue a very prudent approach, so that every crop included in the five systems exist or did exist, in a recent past, in the region.

From the results presented in Table 8, we can underline the low economic results of the rainfed systems. However, we should notice, once again, that the good results achieved by the irrigated systems are very dependent on the water price considered - 10 esc/m³ – and the non consideration of any penalty due to the exceeding of the Portuguese quota (sunflower, sugar beet, dwarf wheat and tomato).

The comparison between the margins obtained in the rainfed innovator system and the irrigated traditional system poses an additional question: if it is possible to find rainfed alternative systems that produce higher economic returns than the irrigated traditional system, then it is possible that many farmers should opt for not irrigating their lands. In fact the small increase in the margin, 13 contos/ha, achieved by the transition from the rainfed to the irrigated system, hardly justifies the necessary investment to pursue that transformation. We should notice however, that the risk associated with the agricultural activity, measured by the annual inter variability of the productivity, is completely different in the two cases, being of course much lower in the irrigated system.

The large expansion of the irrigation schemes in the Alentejo region dominated by the Alqueva dam, clearly poses the question of the need to develop new crops and systems options. The irrigated innovator and the irrigated horticultural systems seem to be, according to the assumptions

Table 8. *Estimation of the annual average margins for the actual representative and the elected potential cropping systems in the Odivelas irrigation scheme (2005 scenario; escudos/ha)*

| Cropping Systems | Year 1 | Year 2 | Year 3 | Year 4 | Annual Average margin |
|---|---|---|---|---|---|
| Irrigated innovator horticultural system | Broccoli - Potato | Melon | Broccoli – Green pepper | Onion | |
| margins | 725083 | 184327 | 694927 | 302716 | 476763 |
| Irrigated innovator system | Tomato industry | Wheat dwarf rain irrigated system | Sugar beet | Sunflower rain irrigated system | |
| margins | 537842 | 102662 | 121760 | 36001 | 199566 |
| Irrigated traditional system | Maize corn | Sunflower rain irrigated system | | | |
| margins | 27334 | 36001 | | | 31668 |
| Rainfed innovator system | Wheat dwarf rain fed | Rye grass silage | Sunflower rain feed | | |
| margins | 84457 | 18380 | 36409 | | 46415 |
| Rainfed traditional system | Sunflower rain fed | Fallow | | | |
| margins | 36409 | 0 | | | 18205 |

imposed, the most promising and possible options. However, this poses another kind of problems, not easier to deal with, and that until now are somewhat forgotten. In fact, the success of such systems relies not only on agronomic and technological aspects, but also, and we may even say mainly, on CAP, chain food and marketing developments. Negotiations with the European Union, to make the Portuguese quotas flexible in several agricultural products – processing tomato, dwarf wheat, sunflower and sugar beet – are required not to suffer penalties from exceeding quotas. Installation of an extra capacity of agricultural processing industries is also required. And last but not least, it is necessary to develop a true marketing-oriented attitude in farmers and production associations. The search for new and bigger markets, farther than the traditional ones – local or national markets – is crucial to support and stabilize prices of fresh consumption products. This of course requires a strong logistic capacity and a developed commercial distribution net.

## Conclusions

Ryegrass, sunflower and dwarf wheat are the only traditional rainfed crops that sustain margins over 10 contos/ha. On the other hand, the traditional irrigated crops, such as maize and sunflower, also don't seem to be great economic alternatives in the future. The economic analysis of sensibility to the water price variation performed, reveals that between 13 esc/m$^3$ and 20 esc/m$^3$ water prices, every traditional irrigated alternative crop is economically unviable. So the future crop alternatives for the Odivelas irrigation scheme have to be found among new crops and systems that are more economically valuable and less water consuming. Those could include low input extensive irrigated crops, like sugar beet and dwarf wheat, and high input intensive irrigated crops, like horticultural crops for fresh consumption or processing. The success of the expansion of irrigation schemes in the Alentejo region then relies on the development of actions/policies that allow and support the development of those crops. Among these actions we can suggest the following priorities:

- Imposing limitations on water use. Lack of water has been one of the major limitations in the large irrigation schemes in Alentejo and could be still a problem in the future. Limitations should be imposed on the total water volume per hectare which farmers are allowed to use. Alternatively, the price of the water should be set in order to promote a rational water use. The price of water can also be gradually increased if farmers exceed a pre-specified volume per crop and per hectare (differential pricing).
- Subsidising price of water; implementing fixed land taxes. The uptake of irrigation can be severely affected by price of water. In the first stage of life of a new irrigation scheme, the price of water could be subsidised or conditions developed to allow the cultivation of high-income crops. A feasible way of doing this is to subsidise water in the first years and gradually increase the price after creating the conditions to allow the cultivation of high-income crops. In parallel, and to increase the adoption of irrigation, farmers can be charged a fixed tax per hectare even if they do not irrigate. This would encourage them to either irrigate or rent or even sell their land.
- Developing extension services. The unwillingness of farmers to adopt new crops and production techniques could be an important limitation. Inexpensive solutions, rather than ambitious proposals, seem to be needed in Odivelas. The provision of an agronomist by the future association of farmers is likely to be a cost effective alternative. This could be complemented with the installation of demonstration fields with specific purposes (e.g. increase the adoption of a particular crop irrigation method). More elaborate alternatives should not be excluded. The creation of an Irrigation Technology Centre, with broader objectives (e.g. research and education in irrigation) and from the perspective of all irrigation schemes under the influence of the Alqueva dam, for instance, is clearly a possibility.
- Developing marketing and processing facilities. Lack of crop marketing and processing facilities is likely to be the main reason why most farmers do not cultivate high-in-

come crops, such as vegetables and crops for industrial processing in the large irrigation schemes of Portugal. The development of infrastructure to deal with these crops (e.g. selection, packing and storage units to deal with vegetables for fresh consumption; common conveyance facilities to deal with large-scale industrial crops such as sugar beet) should be a priority in Odivelas.

- Providing irrigation equipment and farm machinery to rent. The provision of farm machinery and irrigation equipment to rent by the association of farmers of the irrigation scheme is one of major contributions to support the adoption of the irrigation by small-scale farmers. The introduction of new crops reinforces the need for specific new machinery and irrigation equipment. This should be provided by the association of farmers and must be considered together with parallel initiatives to support infrastructures investment by farmers.
- Modifying land tenure legislation. Land tenancy legislation does not favour renting. Partially as a consequence, there are farmers who have suitable land in the irrigation schemes in Alentejo and do not irrigate and farmers who irrigate that are willing to increase their scale of operation. There is a clear need to modify the current legislation in order to stimulate renting in potentially irrigable areas.
- Reassessing field size limitations and considering alternatives to improve the performance of small fields. There is a direct relationship between field size and performance of the irrigated areas. However, the complexity of this issue and the large number of small fields in the Odivelas scheme suggest the need for further assessments. All the alternatives available should be evaluated, from excluding the smaller fields to different forms of land consolidation.
- Reassessing soil conditions: drainage, salinity, pH and slope. There is only a small area in the Odivelas scheme with serious drainage limitations. But improving an integrated drainage system should be a priority in the development of the entire scheme. Soil salinity may increase with irrigation and become a major problem in some soils. Salt content should be carefully monitored and preventive measures must be adopted if necessary. The majority of the potential irrigable areas of Odivelas have soils with unfavourable pH values (i.e. pH<6 or pH>8). These soils should be further assessed in order to improve their conditions if possible or otherwise excluded from the scheme area. The same should happen to fields with unsuitable slopes (steep) for irrigation.

The success of agricultural activity in Alentejo is not guaranteed by the development of irrigation schemes. The presence of water should not be seen as an end but just as a beginning of a new farming era in the region. The potential and the development of new irrigation schemes seem to be a unique opportunity to support and sustain the Alentejo agriculture and their farmer's incomes. It is then necessary and essential to identify, promote and support all the actions and policies that effectively contribute to achieve the best possible result.

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