Economic sustainability of Spanish table grapes in different water and technology contexts

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Abstract

Eighty-five percent of Spanish table grapes are produced near the Mediterranean Sea, in very arid regions. The irrigation-water availability influences the cropping plans adopted on farms and, on the medium-term, it will also influence viability and competitiveness. This work is aimed at analysing the effects of the main technological improvements introduced on farms and determining the economic consequences, derived from other production scenarios characterized by variability in irrigation-water supply and price. Mathematical programming has been applied to models established for representative farms in Murcia and Alicante. After obtaining the most direct results of investment in technology, the modelization shows that the on-farm water availability exerts a greater effect than the water price, and that only technologically equipped farms can face increases in the price of this resource, keeping their economic sustainability constant.

Key words: crop planning, irrigation-water price, irrigation-water supply, mathematical programming, *Vitis vinifera* L.

Résumé

85% du raisin de table espagnol est produit à proximité de la Mer Méditerranée dans des zones arides. La disponibilité de l'eau d'irrigation influence la planification cultural des exploitations agricoles et, au moyen terme, elle va aussi présenter des répercussions sur la viabilité et compétitivité des exploitations. Ce papier a l'objectif d'analyser les principales innovations technologiques introduites dans les exploitations agricoles et de déterminer les conséquences économiques qui dérivent d'autres scénarios caractérisés par une forte variabilité de la fourniture et du prix de l'eau d'irrigation. Un programme mathématique a été appliqué aux modèles établis pour les exploitations les plus représentatives de Murcia et Alicante. Après avoir obtenu les résultats les plus directs des investissements pour le développement technologique, la modélisation montre que la disponibilité d'eau dans l'exploitation agricole a un effet plus important que le prix de l'eau même, et que seules les exploitations les plus avancées du point de vue technologique arrivent à faire face à l'augmentation du prix de cette ressource, tout en maintenant constante leur durabilité économique.

Mots-clés: programme culturale, prix de l'eau d'irrigation, fourniture de l'eau d'irrigation, programme mathématique, *Vitis vinifera* L.

1. Introduction

Spain, with 15.2% of the vine-planted surface area in the world, is the leader in terms of extension this crop covers. Although only 5% of this production is destined to fresh consumption, as in other Mediterranean countries, cultivation of table grapes (*Vitis vinifera* L.) is important (OIV, 2005) given its long tradition. In recent years, the surface area dedicated to Spanish table grapes has diminished at an alarming rate, by 64.5% between 1990 and 2005, although production has only decreased by 34.5% during the same period (MAPA, 2006). To a great extent, this is due to the adoption of innovation, which has caused an increase in yields.

Despite this gradual reduction in production, Spain is the fifth table grape producer worldwide in the northern hemisphere, and the second in Europe, surpassed only by Italy. It is the sixth exporter in the world, coming after Chile, Italy, the USA, South Africa and Mexico. In 2005, Spain exported 113,823 tons of fresh grapes, of which 99% were destined to European countries (MAPA, 2006), while the markets of the main importer in the world, the United States, are well supplied by Chile and Mexico (Nahuelhual, 2005). In recent years, both globalization and the reduction in tariff barriers have generated an increase in the volume imported by Europe from third countries. This phenomenon has also taken place in producing countries, like Spain or Italy, which, between 2002 and 2003, increased their imports by 12.3% and 15.1% respectively (OIV, 2005). Such an influx of grapes from the southern hemisphere, besides representing a direct competition for European production, disrupts very traditional markets, where the seasonality of this fruits has always been an advantage. On the other hand, the new varieties that are reaching Europe broaden the consumer choice and create new demands (Piva *et al.,* 2006), as it happens with the seedless grapes, which is a motive for the farmers continuous need to adopt technological novelties. Given the predominance of Italy and the competition from other countries outside the Union, the Spanish table grape-producing farms must optimize the production phase, which means they must overcome the limitations related to irrigation water and make a strong bid for innovation. Both aspects must be analyzed from an economic perspective.

Seventy-one percent of the Spanish grape-growing areas are located in the provinces of Alicante and Murcia (Southern-Eastern Spain), which supply 55% and 31% of the na-

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tional production, respectively. Both these regions are situated next to the Mediterranean Sea, they have a warm climate but are greatly lacking in rainfall, with average precipitation below 300 mm per year. Water is the scarcest and most valuable natural resource, given the over-exploitation of aquifers or its low quality, and it is the main reason why this crop is totally or partially abandoned. Plots under marginal management are common, i.e. they are left to basic care for a certain amount of time, which habitually consists of maintenance pruning and minimum tillage. If the circumstances that have favoured this situation (scarcity of irrigation water, lack of personal and economic incentive of the agricultural producers, etc.) are longer lasting, then this abandonment becomes definitive. Rejecting optimum crop management is a common practise in these regions of production, and faced with the lack of irrigation water the choice is to destine the available quantity to the most economically viable plots. Furthermore, the farms are very small in size, 72% of those in Alicante and 66% of those in Murcia are smaller than 5 ha (INE, 2005), thus the sustainability of this crop depends on being able to reduce marginal management and overcome water limitations. Improving the level of technology in the production phase could help to achieve this objective.

After identifying the aspects of production that are susceptible to improvement in the two main regions of production (Valle del Vinalopó in Alicante, and Valle del Guadalentín in Murcia), the objectives of the present work are to analyse the consequences of introducing the said improvements and determining the economic effects of the other possible scenarios for future production, where the average water supply varies and there is a gradual increase in the price of irrigation water. The posed scenarios will be analysed by linear models that will be resolved by mathematical programming.

2. Technological development of Spanish table grapes production

In the Valle del Vinalopó (Alicante), there are 9,500 ha of grapes (MAPA, 2006), forming a well-defined agrarian system that has remained very stable over time. Its most defining feature is its «bagging», by which bunches are covered by a paper bag, from a little before colour change up to harvesting. In this way, grapes can remain on the vine for longer, bunches are more uniform in colour and they are protected from damage caused by climate or pests, and they are not in dire ct contact with phytosanitary products, a practice strongly reducing the amount of residues in the final product. Bagging is carried out by hand and it seems to allow for little innovation, at least in terms of its possible mechanization. In this region, farms are small and have a certain family character, there is an ageing of the agrarian population and generational take-over is guaranteed in only a few cases. Technology is found at an acceptable level, and it is based more on habits and experience than on innovation transfer, which takes place slowly, not only due to resistance to changing the system, but also because adaptations are not easy, given this is a very traditional and manual crop. Despite all this, it is possible to improve the mechanization of the labour, by increasing the power used and generalizing the use of «tying machines» for green pruning and «shredders» for pruned residues.

The variety composition has undergone scarce variation over time, and it is fundamentally based on Italia and Aledo varieties, although important changes are foreseeable in the coming years. With the new market demand, it seems predictable and inevitable that some early and seedless varieties will be introduced, which are still in minor representation. The most common training system is the espalier with three wires (the Aledo variety only uses this support), followed by the trellis (in the Italian variety), but another support structure is spreading, the one having a «Y» shape, taller than the currently used one, which facilitates treatment application and improves the relationship between the green material and the number of bunches.

The situation is different in the province of Murcia, where the surface cultivated with grapevines has increased in recent years, reaching 6,176 hectares in 2004 (CARM, 2008) and where new production zones have appeared, with large business producers and a strong bid for seedless varieties. In general terms, it would possible to talk about family-run farms, but the important investment in capital and technology makes the difference when the two provinces are compared. There is intense activity for the introduction of new plant material, traditional varieties like Italia and Ohanes have diminished, and there has been an increase in the surface planted with Dominga, Napoleon and above all seedless and early varieties. This is the case of Superior, Crimson and Red Globe, which seem to be the most widespread in the province (Carreño *et al.,* 2006). The structure upon which vines are trained, the so called trellis, was traditionally made of wood but it has been modernized and is now in galvanized iron. It is common to cover the vineyards with anti-hail nets, which also act as wind-breaks, plus some seedless varieties are also covered with a plastic film, which favours earliness of grapes and improves the final fruit quality. Correct crop management requires a careful pruning, especially the green pruning, and for the grapes quality to be optimum, cultivation requires important management. On the other hand, the level of mechanization is acceptable, although it is still possible to increase the power and effectiveness of the machinery, particularly in the case of the phytosanitary treatments.

Currently, in both regions, the growing operation being perfected most is irrigation, which is bringing about massive implementation of drip irrigation. This type of irrigation covers 50% of the surface area at present, and it is foreseeable that it will reach 90% soon. Drip irrigation offers great advantages over traditional flood irrigation, such as the reduction and better distribution of the flows applied, and the possibility of programming the supply by adjusting it to the growing cycle. The shortage of irrigation water in these zones, the irregularity of the supplies and, the deficiencies in the quality, also encourage grape-growers to construct accumulation reservoirs, which are more widespread in the Murcia region.

Therefore, technological improvements more quickly adopted in Spanish table-grape cultivations are: increase in the average power of the machinery to carry out tillage and the phytosanitary treatments, use of tying machines for summer pruning, use of pre-pruning machines (in espaliers), generalized use of shredders for the pruning residues and replacement of the traditional irrigation systems with programmed drip irrigation. Moreover, these improvements that are beginning to spread to the new training systems (higher espalier in Y in Alicante) with the use of nets or plastic covering that common in Murcia (Fernández-Zamudio *et al.,* 2007).

To all these technological innovations, we must add the novelty of the plant material, an aspect in which variation is continually being introduced. Among the large group of varieties found in the region, in our analysis we considered the incorporation of the early variety Victoria and the seedless variety Superior in Alicante, and the variety Crimson in Murcia. Alcaraz-López *et al.* (2005), Alonso *et al.* (2006) and Núñez-Delicado *et al.* (2005) analyse the agronomic behaviour of these new varieties.

3. Information and methodology

Like other agricultural producers, grape-growers base their decision-making on obtaining the greatest possible economic profit from their farms. To do this, they must overcome the main limitations affecting the productive process, which means that crops have to adapt to irregular water availability in the Mediterranean region. Among the works analysing the irrigation needs of table grapevines, the ones by Rana *et al.* (1999 and 2004) and Palma *et al.* (2000) have to be mentioned.

Besides the scarcity of this natural resource, another important limitation could be their price, which is gradually increasing, together with the increase in production costs and in the final farmers' income. In scientific literature there are numerous studies on the economic effects of the adoption of one type of irrigation system or another, or on the application of different water policies: Gurovich (2002) studied the energy cost of irrigating Chilean table grapevines; Hearne and Easter (1997) investigated the impact of applying water prices to the cultivation of fresh grapes; Bazzani *et al.* (2004) studies the effects of putting into practice the Water Framework Directive in Europe; Jorge *et al.* (2003) carried out an economic evaluation of the consequences of drought on the Mediterranean crops and Fernández-Zamudio *et al.* (2007) obtained irrigation water demand curves for the Spanish table varieties.

After establishing the most common technical itineraries in each zone for each grape variety and the different cultivation modes, net margins per hectare, the total needs for manual labour and irrigation water, and their distribution throughout the season were determined. Afterwards, we set the cropping plan, which maximizes the total net margin of the farm, simultaneously optimizing the available resources. To do this, models were established and resolved by mathematical programming. Crop planning is one of the main objectives of agronomic engineers and agricultural economists, and mathematical programming is one of the most commonly used tools to quantify the effects of passing from one productive context to another, on the basis of the resources available. Some of these applications are the works by Ray and Williams (1999), El-Awar *et al.* (2001), Aulagnier *et al.* (2002), Conradie and Hoag (2004) and Castro *et al.* (2005).

The objective function is defined by:

$$Max \sum_{i=1}^{n} NM_i \cdot X_i$$

where, NM_i is the net margin, and X_i is the surface area cultivated for the growing activity *i*. In turn, the net margin is *NM=I-Cf-Cv*. In other words, from the income, *I*, of each activity, the fixed costs are subtracted, *Cf*, which include the amortization of the drip irrigation system, structure of the conduction, type of covering etc., and also the variable costs, *Cv*, in which manual labour is not included, should be compensated with the result of the objective function. To

Table 1 – *Decisional variables of Spanish table grapes: description, net margin for scenarios and annual water supply.*

Area [1]		Variables description	Irrigation type	Scenario	Q_i [2] (m^3/ha)	Net Margin [3] Scen.-1 (€/ha)	Net Margin [3] Scen.-2 (€/ha)
A	A1	Aledo.Traditional espalier. Bagged	Flood	1& 2	3900	7311	7430
A	A2	Aledo. Traditional espalier. Bagged	Drip	1& 2	4000	8156	8015
A	A3	Aledo. Y espalier. Bagged	Drip	1& 2	4000	8999	8836
A	A4	Italia. Traditional espalier. Bagged	Flood	1& 2	3900	5000	4917
A	A5	Italia. Traditional espalier. No bagged	Flood	1& 2	3900	5233	5158
A	A6	Italia. Traditional espalier. Bagged	Drip	1& 2	4000	4916	4872
A	A7	Italia. Traditional espalier. No Bagged	Drip	1& 2	4000	5638	5582
A	A8	Italia. Trellis. Bagged	Flood	1& 2	3900	5199	5247
A	A9	Italia. Trellis. Bagged	Drip	1& 2	4000	6168	6223
A	A10	Italia. Y espalier. Bagged.	Drip	1& 2	4000	5934	5771
A	A11	Victoria. Y espalier. No bagged	Drip	2	3500		7931
A	A12	Superior. Y espalier. No bagged	Drip	2	3500		10866
A	A13	Marginal management		1& 2	0	-720	-720
M	M1	Napoleon. Wood trellis	Flood	1& 2	5100	4433	4589
M	M2	Superior. Wood trellis	Flood	1& 2	5100	7224	7014
M	M3	Italia. Wood trellis	Flood	1& 2	5100	3675	3679
M	M4	Dominga. Wood trellis	Flood	1& 2	5100	6995	6959
M	M5	Red Globe. Wood trellis	Drip	1	4620	7112	
M	M6	Superior. Wood trellis	Drip	1	3990	8754	
M	M7	Superior. Galvanized-iron trellis	Drip	2	3990		7939
M	M8	Red Globe. Galvanized-iron trellis. Mesh cover	Drip	2	4620		6163
M	M9	Superior. Galvanized-iron trellis. Mesh cover	Drip	2	3990		13573
M	M10	Superior. Galvanized-iron trellis. Mesh & Plastic	Drip	2	4550		15635
M	M11	Crimson. Galvanized iron-trellis. Mesh cover	Drip	2	4860		17590
M	M12	Marginal management		1& 2	0	-787	-787

1) Areas: Alicante (A), Murcia (M)
2) Q_i is annual water supply for i activity
3) Net margins excluding labour cost
Source: Own elaboration (year 2005)

calculate the income, average production has been taken for each zone, and the mean prices of the grape, as received by the producers. The prices have been taken from the regional agricultural statistics, and refer to the period 2002-2005 (CAPA, 2008 and CARM, 2008).

The decisional variables, or the unknowns, will be the surface areas occupied by the different growing activities. Table 1 describes the modelized variables, together with their annual water allotment and the net margins in the two technological scenarios analyzed.

The repercussions of passing from one productive context to another is analysed by the modelization scenarios. Scenario-1 represents the traditional production conditions for table grapevines in the two zones. Then, we pass to another productive context, where a series of technological improvements was adopted, towards the scenario that the two zones would appear to be moving towards according to regional agricultural technicians (Scenario-2). Subsequently, assuming that the proposed improvements are accepted in Scenario-2, different contexts of irrigation-water availability are analysed, changing both the price of the resource and the annual and monthly water allotment the farm receives (Scenarios 2a, 2b and 2c). Although the criteria for an increase or reduction in the volumes of water have been similar in both areas, one begins with somewhat different reference values, seeing that in the Murcia region the current supply is somewhat higher than in Alicante, and it is common to have an irrigation pool on farm, which allows for a more efficient monthly distribution. Tables 2 and 3 summarise the basic characteristics of the different scenarios.

Table 2 – *Technological characteristics of modelization scenarios.*

	Scenario-1	Scenario-2
Improvement of technology (A & M):		
Power of machinery	Medium-low	High
Tying machine	no	yes
Pre-pruning (in espalier)	no	yes
Shredder for remnants of pruning	no	yes
Restrictions in surface for technology adoption or market (α):		
Surface with drip irrigation (A & M)	< 30%	< 90%
Surface with Y espalier (A)	< 30%	< 50%
Surface with mesh or plastic covering (M)		< 45%
Market restrictions:		
Aledo (A)	< 45%	< 45%
Victoria (A)		< 10%
Superior (A)		< 5%
Crimson (M)		< 10%

(A) Alicante, (M) Murcia

Table 3 – *Prices and water supply in modelization scenarios (Data for family-run of 4 ha).*

Scenarios	Reference value 1 & 2	Deviation from reference value 2a	2b	2c
Price (€/m^3)	0.18	Idem	Rises 28%	Rises 50%
Annual supply in Alicante (Wa)	14000	Low 15%	Rises 10%	Rises 35%
Monthly* supply in Alicante (Wm)	2850	Idem	Rises 10%	Rises 35%
Annual supply in Murcia (Wa)	15000	Low 15%	Rises 10%	Rises 35%
Monthly* supply in Murcia (Wm)	5650	Idem	Rises 10%	Rises 35%

(A) Alicante, (M) Murcia
Supply in m^3. * Irrigation period: from March to September

Given that in both regions of production agriculture is a family-run activity, calculations have been applied to a farm being representative of the two counties, with four hectares and family worker availability of one agricultural AWU (Annual Work Unit corresponding to 1,920 hours a year).

Below, we will show the fundamental restrictions of the models and their mathematical expression. In all cases, n is the number of growing activities and X_i the surface area of the activity i:

1] Surface area. The cultivated area Sc cannot exceed the available surface Sa, which is 4 hectares.

$$\sum_{i=1}^{n} X_i = Sc \text{ and } Sc \le Sa$$

2] Manual labour. Labour (l) is preferably done by the owner, and the hired manual labour contracted monthly (hl_q) is only for what the owner cannot do (fl_q).

$$\sum_{q=1}^{4} hl_q = \sum_{i=1}^{n}\sum_{q=1}^{4} l_{iq} \cdot X_i - \sum_{q=1}^{4} fl_q$$

3] Technology and market. The maximum surface area that can adopt technology (T) is limited by scenarios 1 and 2 to a percentage of the cultivated area, according to the limits (α) that are shown in Table 2. This restriction affects the grape-growing surface with: drip irrigation, net or plastic covering, and Y-shaped espalier.

$$\sum_{i=1}^{n} X_{iT} \le \alpha \cdot Sc$$

The same approach is used for varieties that are restricted by the market (M), which are Aledo, Victoria, Superior and Crimson.

$$\sum_{i=1}^{n} X_{iM} \le \alpha \cdot Sc$$

4] Irrigation-water supply on farm. Maximum water availability is limited per month (Wm) and per year (Wa), Table 3. Water consumed by each growing activity is Q_i, and is shown in Table 1.

$$\sum_{i=1}^{n}\sum_{m=1}^{12} Q_{im} \cdot X_i \le Wm$$

$$\sum_{i=1}^{n} Q_i \cdot X_i \le Wa$$

5] Marginal management. The planted surface area with marginal management should account for maximum 30% of the available surface area on family-run farms, or likewise:

$$\sum_{i=1}^{n} X_i \ge 0.7 \cdot S_a$$

4. Results and discussion

Table 4 shows the cropping plans obtained from the modelization of each scenario and the corresponding farm net margin. The cost of the hired seasonal labour, calculated at a market price, is deducted from that result, whereas the work carried out by the land-owner must be compensated for in the solution.

Table 4 – *Cropping plan and results for scenarios.*

Proportion of activities (in %)[1]	Irrigation Type	Scenarios 1	2	2a	2b	2c
ALICANTE:						
A2 Aledo. Traditional espalier. Bagged	Drip	40.5	40.5	40.5	40.5	40.5
A3 Aledo. Y espalier. Bagged	Drip	4.5	4.5	4.5	4.5	4.5
A5 Italia. Traditional espalier. No bagged	Flood	24.9				
A7 Italia. Traditional espalier. No Bagged	Drip	5	27.9	14.75	36.6	40
A11 Victoria. Y espalier. No bagged	Drip		10 *	10 *	10 *	10 *
A12 Superior. Y espalier. No bagged	Drip		5 *	5 *	5 *	5 *
Proportion with marginal management		25.1	12.1	25.25	3.4	0,0
Cultivated surface (ha)		**3.0**	**3.5**	**3.0**	**3.9**	**4.0**
Total labour (h)		**1194**	**1155**	**1089**	**1198**	**1215**
Total water consumption (m^3)		**11888**	**14000**	**11900**	**15400**	**15940**
Total Net Margin (€)		**18863**	**24386**	**21291**	**25617**	**25808**
MURCIA:						
M1 Napoleón. Wood trellis	Flood	35	18.8	7.8	26.2	35
M4 Dominga. Wood trellis	Flood	5	10	10	10	10
M5 Red Globe. Wood trellis	Drip	2.5				
M6 Superior. Wood trellis	Drip	40.0	0	0	0	0
M9 Superior. Galvanized iron trellis. Mesh cover	Drip		45	45	45	45
M11 Crimson. Galvanized iron trellis. Mesh cover	Drip		10 *	10 *	10 *	10 *
Proportion with marginal management		17.5	16.2	27.2	8.8	0,0
Cultivated Surface (ha)		**3.3**	**3.4**	**2.9**	**3.6**	**4.0**
Total labour (h)		**1662**	**1936**	**1766**	**2049**	**2185**
Total water consumption (m^3)		**15000**	**15000**	**12752**	**16501**	**18306**
Total Net Margin (€)		**19028**	**32443**	**31008**	**32507**	**32900**

1) With respect to the total surface (4ha)
* Limit coincident with the restrictions of the models
Source: our own calculation

Due to technological improvements, new varieties are introduced in all Scenarios 2, by replacing the more traditional growing techniques. An increase in the net margin is to be added to the cropping diversification, as explained later on.

In Alicante, the introduction of extra-early varieties is expected, for example the Victoria variety and seedless varieties such as Superior, although the latter will present some limitations given they do not seem to adapt to the existing agro-climatic conditions. In any case, traditional varieties such as Aledo and Italia will still be significantly representative of the area, even when using bagging, because they are the best adapted varieties and they are commercially backed by their Designation of Origin.

In Murcia, the varietal map is more varied and it will probably become more dynamic; hence, the complete replacement of the traditional Napoleon and Dominga is expected within a few years. The future trend might focus on the extra-early varieties that can be forced by covering the plants (net or plastic films). Crimson and the Superior seedless variety (that is also early), preferred to the Red Globe, are obtained from the modelization.

An important aspect is the proportion of surface subject to marginal management, which is reduced of 13% in Alicante and in a greater proportion in Murcia when passing from Scenario-1 to Scenario-2. As the irrigation water allotment increases (Scenario-2b), the proportion of marginal crops is reduced; when allotments are 35% over the standard average (Scenario-2c), the ideal cultivation of the whole farm area is accomplished.

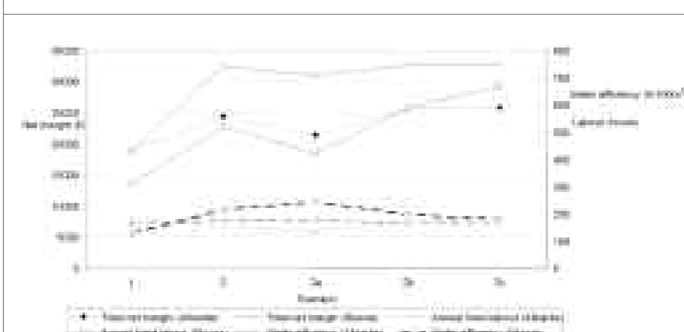
The used irrigation water is in keeping with the allotted amounts applied, given that the irrigation applied is usually inadequate considering the theoretical needs of the crops in that area. Cropping plans show a very low consumption (considering the total annual expenditure per number of available hectares), never having exceeded 4,000 m^3/ha in Alicante nor 4,600 m^3/ha in Murcia. When assessing the effect of different water irrigation allotments, it is firstly necessary to analyse a situation of shortage, typical of a drought period, where the annual water allotment (and not the monthly maximum quantity that is maintained) can be reduced by 10% (Scenario-2a). In this case, a decrease in the net margin of 12.7% in Alicante and 4.4% in Murcia is expected. The water shortage will have a direct effect on the surface with marginal management, which will increase of 13.2% in Alicante and of 11% in Murcia with respect to Scenario-2.

In addition to the results shown by Table 4, figure 1 graphically represents the trend followed by the farm's net margins, the seasonal labour requirements and the water irrigation efficiency; the latter has been obtained by the quotient of the total net margin and the annual volume of water used on farm. When going from scenario 1 to 2, the net margin can increase of 29% in Alicante and of 71% in Murcia, and continues with an increasing trend when water allotments exceed the current amount.

Regarding the manual work, in Alicante the total work decreases of 3.3% in Scenario-2, while hired labour is reduced of 11.3%. Something very different occurs in Murcia, where not only the annual work increases of 6.3% in scenario-2, but also the seasonal labour required increases of 69%, due to the new varieties needing more manual operations.

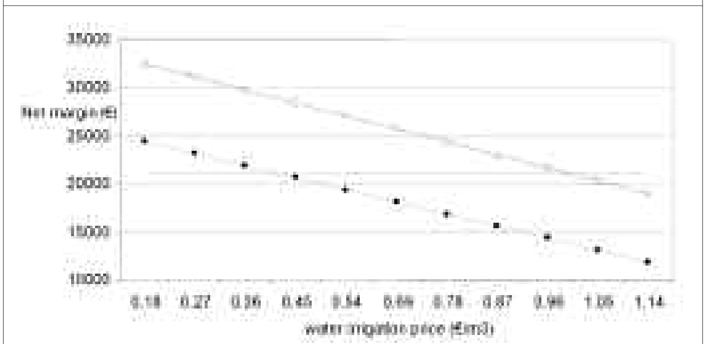
Lastly, the irrigation water's efficiency increases according to the technological level of the farm and it is higher in the Murcia region. The higher value is obtained in Scenario-2a, where the technological improvements enable a very high economic efficiency per cubic meter of irrigation water used (1.74 euros in Alicante and 2.16 euros in Murcia).

Figure 1 – *Results of modelization for the Spanish table-grape (Data fpr 4 family farm).*



Finally, the effect of a gradual increase in water prices has been simulated, based on the technological and water conditions of Scenario-2, and the first fact to be established is that producers from Murcia can withstand the price increase better than producers from Alicante (Figure 2). The obtained net margins decrease as the water price increases. Said economic result should serve to compensate the land owners work, thus if a minimum income of 21,000 euros is intended, the water price should not exceed 0.96 €/m^3 in Murcia or 0.36 €/m^3 in Alicante. These values will be much lower in practice, given that the calculations consider the decrease in the farm's net margins to be exclusively due to the water cost increase, while it usually happens together with the increase of other costs, such as the energy cost of the pumping.

Figure 2 – *Net margin trend according to water irrigation price (Data for a family-run farm of 4 ha).*



5. Conclusions

To guarantee the continuity of the Spanish table grape-growing farms (most of them being small and family-run), the adoption of technological improvements seems to be essential, as well as the introduction of new varieties (extra-early and seedless), supplementing and widening the commercial calendar of traditional varieties. The vehicle fleet should likewise be modernized and the use of tying machines, pre-pruning and pruning-remains shredders should be extended whenever possible. With such improvements the increase in the number of plots with new training structures (espalier in Y, in Alicante) and of those covered with nets or plastic films is expected in Murcia.

An essential improvement (being massively applied in both areas) is the increase of surfaces watered with the drip irrigation system, a technique that enables the choice of the watering times for the plots, by achieving an optimization of the allotments awarded in the plantation, that are usually lower than the theoretical needs of the crops. An increase of 35% of the initial volumes in our calculations was required in order to ideally cultivate the whole farming area. This does not imply a genuinely high consumption, being less than 4,000 m^3 a year per hectare in the case of Alicante, and less than 4,600 m^3 in Murcia (scenario-2c). These volumes are wholly acceptable for these areas from the hydrological point of view, given that any other horticultural crop, even citrus, requires greater irrigation water allotments.

In view of the studied increasing water prices, minimal changes noted in the response show that the problem of these producing areas is the water availability itself and not its price. Even if the grape-growing farms maintain their current income, something hard to anticipate, they will not be capable of withstanding a heavy increase in irrigation costs. Thus, water becomes a key resource and an important limiting factor for this agriculture, on the one hand because in the Mediterranean irrigation is essential to obtain the commercial production of fresh grapes, and on the other hand because if water prices are very high, only the more profitable farms can afford to pay for irrigation, by reducing the chances of survival of family-run agricultural activities.

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