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Economic valuation of water and «willingness to pay» analysis with repect to tropical fruit production in southeastern Spain

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Abstract

This paper reports a survey of how 64 tropical fruit growers from the Granada coast of Spain use and value their water resources. This area produces crops of high added value. The agricultural demand for water is ever increasing and is much greater than the actual supply. This problem is worsened by the infiltration of seawater into the aquifers that provide most of the irrigation water for the area. Moreover, the population increases five-fold in the summer due to tourism, further aggravating the problem of water scarcity. Technical innovations, especially the reuse of urban wastewater, and economic solutions, namely increasing the price of water, have been proposed under the European Union Water Framework Directive. The main questions in the survey are described and the responses analysed. The productive, technological and resource management characteristics that determine the growers' expressed willingness to pay for the water they use, as well as their attitude towards the use of alternative sources (such as residual water) are examined. Finally, the marginal product value of irrigation water in the area is calculated.

Additional key words: economic value of water, tropical fruit production, willingness to pay for water.

Resumen

Valoración económica del agua y análisis de la disposición al pago en la fruticultura subtropical del sudeste español

El presente artículo expone algunos resultados de una encuesta realizada a 64 explotaciones de fruticultura tropical de la costa tropical de Granada sobre el uso y valoración de los recursos hídricos de que disponen. Se trata de una zona de cultivos con un gran valor añadido, en la que la demanda agrícola de agua es creciente y muy superior a la oferta. Esta situación se ve agravada por problemas de intrusión marina en el acuífero del que se surte principalmente la zona, con la consiguiente degradación de la calidad en el agua de riego. Además, la población se quintuplica en verano por el turismo, lo que agudiza el problema. Se han planteado tanto soluciones técnicas (especialmente el uso de aguas residuales depuradas de origen urbano), como soluciones de naturaleza económica (básicamente incrementos del precio del agua), de acuerdo con lo establecido en la Directiva Marco de la Unión Europea. En primer lugar se presenta un análisis descriptivo de las respuestas más importantes de los agricultores a la encuesta. A continuación se estudia qué características productivas, tecnológicas y de gestión de recursos en las explotaciones determinan una mayor disposición expresada por los agricultores a pagar por el agua actualmente utilizada, así como su actitud ante el uso de fuentes alternativas tales como las aguas residuales. Finalmente se calcula el valor del producto marginal del agua de riego.

Palabras clave adicionales: disposición a pagar por agua, fruticultura tropical, valor económico del agua.

Introduction

Tropical agriculture on the Andalusian coast

The first custard apple trees (*Annona cherimola* Mill.) appeared along the coast of Granada during the 1950s. Velázquez (1953) reported 100 ha were given over to this crop in the early part of the decade, a number that has steadily grown to the current figure of approximately 3,200 ha. Custard apple production is some 30,000-35,000 Mg (MAPA, 2002).

Avocado (*Persea americana* Mill.) growing started in the 1970s, increasing from a mere 10 ha in 1970 to more than 2000 ha in 1981 (Calatrava and López,

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1981). Avocados now occupy some 8350 ha, with an average annual production of nearly 70,000 Mg (MAPA, 2002).

The most recent innovation in the tropical sector was the development of standard mango (*Mangifera indica* L.) plantations during the mid 1980s, plus, to a lesser extent, the introduction of other species such as the lychee (*Litchi chinensis* Sonn. Mill.) or star fruit (*Averrhoa carambola* L.). In more recent years, there has been a recovery of the traditional loquat plantations (*Eriobotrya japonica* Thunb. Lindl.). However, most of the cultivated area is committed to tropical fruit growing; avocado and custard apple plantations remain particularly common, covering 66.80% and 25.60% of the cultivated area respectively (Junta de Andalucía, 2000).

Tropical fruit orchards in Andalusia occupy a total area of about 12,500 ha, some of which are still developing. These generate an output worth about €70 million at growers' prices, accounting for approximately 1.25% of the total value of agricultural production in Andalusia, and almost 30% of the value of non-citrus fruit production (Junta de Andalucía, 2000). The socio-economic impact of tropical agriculture at the local level is very important and is on the increase in terms of the generation of direct income, the indirect effect on the demand for production and marketing inputs, and the demand for labour. Tree orchards also help to prevent soil erosion and are an important attribute of the «new Mediterranean» landscape (Calatrava, 1994). Agriculture is the second most important economic activity after tourism. It should be noted that there is strong competition for both land and water between the farming and urban interests in the area.

Granada's tropical coast has a similar rainfall pattern to the rest of the southeastern Spanish coast (average rainfall 500 mm, occasionally as low as 300 mm). The irrigation water used in the area is predominantly groundwater. The demand for irrigation water is highest in the summer, when the urban water demand also peaks. Since the early 1980s, the growth of the cultivated area, plus the summertime peak demand for water, has steadily led to a problem of saltwater infiltration due to overexploitation of the River Verde-Seco aquifer. In fact, its salinity now falls only during years with abundant autumn rainfall (Fernández *et al.,* 1985).

The increasing salinity of the irrigation water available has even made some growers change to more tolerant species. The avocado is particularly sensitive to salinity and the reduction of the area planted with this species during the 1990s favoured the recovery of the loquat. This has a long tradition in the area but was abandoned in the 1980s because of its greater labour requirements, and because the avocado was more profitable. The main reasons for the reduction in the avocado-planted area were its low tolerance to salinity and the unfavourable expectations regarding future water availability. In recent years, improvements in the reliability of the water supply are encouraging new avocado plantations. The crop that has gained ground most in the last few years, however, is mango, largely because of its lower water requirements, both in terms of quantity and quality. Table 1 shows the crop yields and water requirements for tropical fruit trees in the area.

Custard apple plantations have traditionally occupied the flat areas of the river valley, whereas avocado plantations are to be found on the very steep slopes (where the former is not grown). These plantations are developed on terraces which range in width between 2 and 7 m, constructed on hillsides of varying slope. The altitude drop between terraces ranges from 1 to 3 m. The planting framework depends on the crop type, the size of the terrace and the plantation age, generally with 4-8 m between trees.

Table 1. Crop yields and water requirements for tropical fruit trees in the area

	Avocado	Custard apple	Mango	Loquat
Crop yields (Mg ha^{-1})				
In lowlands	—	15-20	—	—
On slopes	7-15	10-15	12-18	14-16
Water requirements (m^3 ha^{-1})				
Furrow irrigation	—	6,500-7,000	—	6,000-7,000
Pressure irrigation	7,000-8,000	5,000-5,500	4,900-5,600	4,500-5,000

Source: survey of growers.

Agricultural water economy of the area

There are two types of irrigation community in the RiverVerde/River Seco area. The traditional communities use surface water for irrigation, while those more recently established rely mainly on groundwater. According to the river basin authority (CHSE, 1998), the River Verde has 19 derivation dams whose water is used for agriculture-water managed for the most part by the irrigation communities. A primary network of poorly maintained channels derives from these dams.

The irrigation communities that use water from wells, soundings and catchments at spring sources are innumerable. Catchments at springs and channels predominate in the upper River Verde basin, whereas there is a preponderance of wells and water transportation through pipes, often overly-large ones, in the lower basin (CHSE, 1998). Another feature of these communities are their thousands of water tanks (which sometimes belong to individual growers). Drip irrigation is the most widely used system, although furrow irrigation predominates in the upper basin and in the custard apple plantations.

One of the main problems concerning water management in the area stems from the great proliferation of irrigation communities that has taken place since the 1990s. These new communities arise from new soundings. The scarcity of the resource has led to a massive increase in sounding and extraction initiatives, as well as the founding of numerous irrigation communities, some of which are still in the process of legalisation. As the age of the plantations increases, water requirements also grow, and growers must look for additional resources by participating in new communities. It is not unusual to find that a plot of land belongs to several irrigation communities at the same time. Apart from the increased costs of water supply facilities that this entails, it also stands in the way of proper resource planning and management, especially as far as estimating consumption is concerned.

With regard to the economic-financial system of the irrigation communities in the area, most members must pay a minimum quota per share depending on the contracted electric power, administration expenses, the amortisation of facilities, repair and maintenance, etc., as well as the cost of the irrigation itself. The minimum quota is usually about €36 per year and water share, while the irrigation quota is between €6 and €9 per irrigation and share. A water share entitles the holder to irrigate during each of his turns with a certain water flow, generally around 60 m^3. The number of shares a grower holds usually depends on the area of his land and crop type. For example, 1 ha of avocado may require between 3 and 4 shares.

In recent times, the Andalusian Regional Government has been weighing up the so-called «Coastal Plan», the main objective of which is to recycle residual urban waters for use in irrigation. This would increase the available resources, while at the same time reduce the drainage of residual waters into the sea. Recycled urban wastewater is a supply source whose health-safety level is comparable to that of other conventional sources, in many cases with similar and occasionally even lower costs. Furthermore, the availability of such a resource would reach its peak during the summertime, when domestic water demand is at its highest. Although it is below the reuse levels of other deficient basins, such as the Segura Basin, the Southern Basin (of which the Granada tropical coast is part) uses approximately 250 annual hm^3 of recycled residual water (MIMAM, 1998).

Another threat to the irrigation sector in the area is the European Union Water Framework Directive. This obliges water authorities and irrigation districts to implement cost recovery schemes through proper water pricing in order to more efficiently manage water resources.

In this context, it is important to analyse fruit growers' attitudes with respect to the price they pay and would be willing to pay for irrigation water, as well as the marginal product value of the water they use and the potential for supply expansion through the use of urban residual waters.

Valuing agricultural water use

The analysis of willingness to pay for water in irrigated agriculture with the objective of establishing tariffs can, according to Young (1996), be approached in various ways. The first is the so-called «residual method», which consists of assigning the difference between incomes and all costs associated with production factors unrelated to water (including the owner's management work) as the value of water. The second is the use of mathematical programming models that allow the shadow price of the water to be calculated. The third is the econometric estimation from current observations of plantations (incomes, costs and water consumption). Finally, hedonic price analysis can be applied using information regarding farmland transactions to estimate the implicit price of water.

According to Young (1996), the use of the residual method is beset by several difficulties. The main problem is the need to take into account each and every one of the costs unrelated to material inputs, which makes it difficult to get a good estimate of the value of water. In addition, if by any chance the crop production function is not known, the residual value or the shadow price of the water calculated is independent of the quantity of water used. Similarly, the residual method can be unwieldy in the case of multi-output production systems. Nevertheless, this methodology is frequently used around the world by public agencies, such as the US Bureau of Reclamation, to establish tariffs on water for irrigation use.

Mathematical programming is better for determining water demand functions in agricultural systems with more than one crop (Young, 1996). It is mainly based on the use of models for assigning area, water and other production factors to different crops. As in the case of the residual method, from which it derives, it is crucial that all possible costs be taken into account. In addition, a production function representing the response of the crop to the amount of water applied must be known. Leontief-type techniques can be used to represent this function by omission. In the case of tree plantations, mathematical programming is seldom applicable, especially since there are practically no agronomic production functions that establish relationships between the amount of water used and the yields of most ligneous crops.

The hedonic price analysis approach is not commonly used because it calls for the collection of a great deal of data. Information regarding farmland transactions is difficult to gather and seldom includes data on water availability. Examples of the application of hedonic price analysis can be found in the work of Crouter (1987), Faux and Perry (1999) and Arias (2001).

The estimation of water demand functions from actual observations is more frequent for urban uses, although these are usually calculated from observations of home consumption and generally use panel data (Gómez and Garrido, 1998) relating quantities consumed to price (different tariff systems), income, and other characteristics of domestic units. In the agricultural setting, water charges are rarely volumetric, which makes it difficult to estimate water demand functions.

Moore (1999) proposed a method for estimating the shadow price of irrigation water, understood as the income lost or gained per additional unit of water, based on estimating an income function when data on income are available, but not on production costs or on profits. This author stated that, if water is regarded as a fixed production factor, its marginal value can be estimated as the derivative of an income function in relation to the amount of available water. As water resources are generally allocated by the authorities and their price and quantity is established institutionally and not by the market, water can be considered a fixed production factor in a manner similar to land [see Moore and Dinar (1995) for a review of related work]. When water is considered as a fixed input, its marginal product value can be estimated by modelling an income function. Having verified that the amount of water used did not depend on its price in each of the areas under study, Moore (1999) calculated an income function. The explanatory variables are the irrigation area (as a proxy of the fixed production factors), the amount of water used, and the prices of the products in each period. From the estimated income function, an expression of marginal income is produced, derived from these characteristics. Substituting for each irrigation zone, the marginal value of the water for each area and time period was found.

The contingent valuation method has hardly ever been applied in the analysis of the willingness to pay for water. Some studies analyse the response to water price in either urban (Thomas and Syme, 1988) or agricultural situations (Garrido *et al.,* 1996). Others focus on the economic assessment of other resource attributes, such as quality (Choe *et al.,* 1996) or supply reliability (Howe and Smith, 1994; Griffin and Mjelde, 2000 - all for urban uses). In most cases, the available information is insufficient to conduct satisfactory regression analyses and to establish willingness to pay for water quantity-dependent functions.

Objectives

The aim of the present work was to establish the production, technological and resource management characteristics of farms and growers that determine a greater willingness to pay for the water now used, as well as grower attitude towards the use of alternative resources, such as residual water. A second objective was to value irrigation water in the area by calculating the marginal product value of water for growers.

Material and Methods

The primary information needed to value water resources in tropical fruit production was gathered from a survey of growers in the area. The survey questionnaire was divided into three sections, with a total of 28 (mostly multiple choice type) questions. The first section asked for general information about the characteristics of the farm (area, number of tropical trees, existing species, irrigation system, quantity and frequency of irrigation water applications, etc.). The second section was intended to identify the present price of water and the expressed willingness to pay for it. The last section aimed to establish the socio-demographic traits of each grower (age, educational level, agricultural training, employment in agriculture, etc.). A pilot survey to test the questionnaire and to introduce any appropriate changes was conducted in June 2000.

After the survey had been structured and the interviewees selected at random, a total of 64 direct, oral respondents were interviewed during the months of July and August. Having completed the interviews, the surveys were carefully reviewed to verify that they were complete and contained no incoherent responses. Incomplete or doubtful questionnaires were discarded. The open questions were then closed taking into account the responses given, and both the questions and answers were codified.

Once the survey data had been filtered, a univariate analysis of the information generated was conducted, followed by a multivariate analysis (using multiple regression) to identify the growers' willingness to pay for water. The explanatory variables considered in the model were grower's age, educational level, attitude towards technological innovations, attendance at agricultural training courses, percentage of avocado trees on the farm, average annual water consumption per hectare and total farm area. Table 2 shows these explanatory variables, as well as their different values.

The price per m^3 that the growers acknowledged as their maximum willingness to pay (WTP) was used as the quantitative dependent variable. The WTP variable was tested for normality using the Kolmogorov-Smirnov test. Since the WTP was not normally distributed, the variable was transformed logarithmically. Once this had been checked for normal distribution, a semi-logarithmic function was fitted to the dependent variable expressed logarithmically by ordinary least squares (OLS).

With respect to the calculation of the marginal product value of water, the survey obtained a series of characteristics of the farms in the sample, such as the area planted with each fruit species, crop yields, product price, and the amount of water used per hectare. An approximate measure of income was calculated from this data. Since no production relationship connecting the amount of water applied to crop yields was known, and since the farm production costs were unknown as well, it did not seem feasible to apply the residual method, much less the mathematical programming model. Further, both part-time and full-time growers were represented, and farm size and structure were extremely varied, making it difficult to adequately assign costs to each farm.

Table 2. Definition of the independent variables in the multiple regression model

Variables	Description
Constant	Constant term
AGE	Grower's age (years)
ED12	«1» yes if uneducated/primary education, «0» if not
ED3	«1» if secondary education (baccalaureate, voc. training, etc.) «0» if not
ED4	«1» if higher education (university), «0» if not
ATT1	«1» if grower adopts new technologies immediately after calculating returns and finding them to be satisfactory, «0» if not
ATT2	«1» if grower waits until some other growers he knows adopt new technologies and he has seen they work well (the first innovators), «0» if not
ATT3	«1» if grower waits until the new technologies produce good results and/or does not adopt them until almost everybody else has, «0» if not
PER AVOCADO	Percentage of avocado trees on the farm
CONSU	Consumption of water per ha (m^3 h^{-1})
COURSES	«1» if the grower has attended any agricultural training course, «0» if not
TFA	Total farm area (ha)

Our proposal was to estimate an income function for the sample of farms following a method similar to that used by Moore (1999), who calculated the respective marginal income function of water, as well as its value for each farm. Since the prices received for the sale of products were the same for all growers, and the available information only amounted to cross-sectional data for one year, the income function to be estimated depended solely on the amount of water used and the crop area. Although Moore (1999) used an aggregate data panel of 13 irrigation districts of California to estimate the income function in his original procedure, it is followed here using individual farms as the sample units.

Quadratic, logarithmic linear and linear logarithmic functional forms were tested, of which the latter turned out to be better adjusted. Two model specifications were estimated. The dependent variable was taken as farm revenue; the explanatory variables were the logarithm of total water use and the percentage of land planted with each crop type.

Results and Discussion

General characteristics of farms in the sample

The average area of the farms was 2.96 ha, a size not significantly different to that estimated for the region by Calatrava and González Roa (1994). Table 3 shows the percentage sampling distribution by surface strata. The largest farm had 38 ha and the smallest 0.40 ha. The most abundant crop was avocado (59.34%), followed by custard apple (25.18%) and loquat (10.22%). The remaining area was occupied by mango.

The average age of the growers was 52 years. Thirty five per cent of these were older than 55; only one was younger than 35. Some 17.2% of the growers engaged exclusively in agriculture, while the remainder were involved in several different activities. Growing was the main activity of 14.1%, the secondary occupation of 43%, and was a marginal occupation of 25%.

With respect to the educational level of the interviewees, 46.9% had finished secondary education while 32.8% had finished primary education only. Only one grower had a university degree in agriculture; the remainder either had no agricultural training (58.7%) or had simply taken a course on agricultural techniques (39.70%). In spite of their low level of agricultural training, 54% of the growers stated that they owned at least one technical book on tropical fruit production.

Irrigation and recycled waste water consumption

None of the growers used furrow irrigation techniques; the most frequent system was drip irrigation (67.8%). Irrigation via micro-sprinkling and diffusers was less common (18.6 and 13.6% respectively). The average water consumption was 5,045 m^3 ha^{-1}, the minimum being 2,000 m^3 ha^{-1} and the maximum 7,000 m^3 ha^{-1}.

When growers were asked about water availability in normal years, the majority (84.4%) stated that they had enough at their disposal to satisfy their crop requirements, although more than half of the respondents were not at all satisfied with the quality of the resource. At least one fifth (15.6%) wished that they had more water available.

Similarly, they were asked how the last drought period during the 1990s had reduced their water availability. Nearly 69% had been affected somehow by the last drought. For 30%, the drought brought a reduction in water availability, for 14% it brought both a reduction in water availability and an increase in irrigation water salinity, and for 25% it led to an increase in water salinity but no reduction in water volume. Therefore, for 39% of growers, the drought

Table 3. Distribution of farms by size

Size	No. of farms	% of farms	Total area (ha)	% area
< 1 ha	25	39.06	18.40	9.72
1-5 ha	30	46.88	66.57	35.17
5-10 ha	6	9.38	43.29	22.87
> 10 ha	3	4.69	61.00	32.23
Total	64	100	189.26	100

Source: calculated from survey data.

brought with it an increase in irrigation water salinity. On 10% of the farms, some parcels of land became salinised. The land in question, was, moreover, given over to avocado growing, resulting in a number of the growers affected by the drought abandoning this crop.

With respect to growers' satisfaction with the management of the water supply system, 87.5% felt quite or very satisfied. One half of them considered that water was currently a factor that placed constraints on their productive activity, mostly due to its poor quality. In fact, only 12.5% spoke of quantity as a limitation. In any event, a growing concern over water resources in the area was apparent.

In most cases, water applications were carried out over a two hour period, depending on the season. The frequency of application varied depending on the season, the average being every two days during the summer, every four in spring, every eight in autumn, and every fifteen days in winter.

With respect to the technical criteria that growers applied to optimise their irrigation planning, 78.1% affirmed that they made their decisions by looking at the weather. Only 15.6% of growers relied on technical advice, and as few as 6.3% used a tensiometer to make decisions regarding the timing and quantity of water applications.

The attitude towards the use of recycled residual urban water was generally favourable. Growers who were willing to use recycled residual urban water at lower prices than those presently charged made up the largest group (51.6%). Similarly, another group (37.4%) were willing to use recycled residual water at the same price that they were now paying for their water. Only 3.1% were willing to pay a higher price than they were currently charged. The remaining 10% were not willing to use recycled wastewater under any circumstances.

Price of water and willingness to pay

According to the survey results, growers paid an average price of €0.14 m^{-3} for their water; the lowest price paid was €0.054 m^{-3} and the highest was €0.192 m^{-3}. The price paid by 70.31% of growers was in the range of €0.13-0.15 m^{-3}. Seventy per cent of those surveyed considered this price «expensive», «very expensive» or «excessively expensive».

With respect to the maximum price the growers were willing to pay for water, the average expressed price was €0.27 m^{-3}; the highest individual price was €0.60 m^{-3}. A majority of growers (68.8%) were willing to pay up to somewhere between €0.21 and €0.36 m^{-3}. The average was somewhat conservative (as the expressed WTP usually is). Calatrava *et al.* (1997) showed that, for an avocado price of €0.72 kg^{-1} (the average price under consideration), an avocado orchard with an average annual yield of 8,000 kg ha^{-1}, paying €0.24 m^{-3} for its water, achieved an internal rate of return (IRR) of 13.75%. At €0.30 m^{-3}, the IRR would be 12.55%.

Table 4 shows the results of the adjusted WTP model or water value function, once reduced to the significant variables only. Educational level and age variables were excluded since they were not statistically significant ($\alpha \geq 0.05$), and their removal improved the goodness of fit of the model (which was very significant - $\alpha \geq 0.0001$). Approximately 66% of the variability in willingness to pay for the water was explained by the variables considered.

Growers who had a larger proportion of avocado trees were willing to pay a higher price for water ($\alpha \geq 0.001$). This is logical since the avocado is much more sensitive to water scarcity and to the subsequent salinity accompanying a prolonged drought.

Growers who attended agricultural training courses were significantly more willing to pay for water ($\alpha \geq 0.0001$). Paradoxically, the general educational level was not found to have any influence on willingness to pay, as discussed earlier. It is reasonable to assume that growers who attend courses and seminars related to tropical fruit production topics with any frequency are more aware of the water issues relevant to the sector. However, many may attend these seminars and courses as a requirement for the receipt of aid and grants. These growers are, to a certain extent, more

Table 4. Results of the multiple regression model

Explanatory variables	Coefficients
Constant	–3.84393 (27.7304)
ATT1	0.05443 (2.05832)
ATT2	0.02477 (0.92314)*
PER AVOCADO	0.00146 (3.7992)
CONSU	0.00003 (6.43395)
COURSES	0.14665 (4.95358)
TFA	0.00621 (3.49201)
Adjusted R^2	0.75962

Data computed from the survey. Student t-ratio in brackets. The dependent variable is the natural logarithm of WTP expressed in euros. * Means not significantly different from reference level ATT3. Variables explained in Table 2.

committed to maintaining their orchards, and are therefore willing to pay more for water in order to achieve this end.

The larger the area of tropical trees on a farm, the greater the grower's willingness to pay for water ($\alpha \geq 0.0001$); a positive scale effect on water valuation was recorded. The most innovative growers were more willing to pay than their less innovative colleagues ($\alpha \geq 0.05$).

Marginal value of water

The Pearson linear correlation coefficient between the amount of water used by growers and the price they paid for it was calculated, and a value of $r = 0.0337$ obtained. Water consumption was not, therefore, significantly related to its price. This shows that the amount of water used depended on institutional decisions beyond the growers' control, and that the water charge paid was not an indicator of the scarcity of the resource. At the current price, growers are willing to use more water than they do, but they cannot because their water allotment is limited. According to Moore (1999), the marginal profit of water can therefore be approximated by estimating the marginal value product of water (i.e., the marginal income from water use).

Table 5 shows the results of the estimated models. For the sake of simplification, the insignificant variables, specifically the proportion of area allocated to loquat, avocado and custard apples, as well as the intersecting terms, have been omitted.

The two adjustments mean that between 87.8% and 89.9% of the variance in farm income can be explained by the total amount of water used and the percentage of land planted with mango trees. The fact that the proportion of mango was inversely related to farm income can be explained by its mostly small share in the plantation area, and that it is not cultivated under optimal conditions. Another reason is that some mango plantations are still to enter their period of maximum production. If this variable were removed from the regression model, the value of the adjusted R^2 would be slightly lower, with no major changes in the estimators.

The marginal income functions with respect to water were calculated by deriving with respect to total water use (Table 5). Estimating the value of the first marginal income function for each farm in the sample provided an average value of €1.52 m^{-3}, with a minimum of €1.32 m^{-3} and a maximum of €2.87 m^{-3}. Applying the second expression, the average value of the marginal income decreased to €1.62 m^{-3}, with a minimum of €1.13 m^{-3} and a maximum of €2.08 m^{-3}. The correlation between the marginal income values estimated for each farm with each adjustment was very high (Pearson correlation coefficient equal to 0.9556).

Table 5. Estimated income functions

Dependent variable	Coefficients: Total income	Coefficients: Logarithm of total income
Constant	–99,771.05 (–14.08)	2.451185 (6.55)
Logarithm of total water	13,305.05 (16.57)	0.802042 (18.93)
% mango	–31,045.4 (–2.64)	–2.023997 (–3.26)
Adjusted R^2	0.898361	0.879788
	Marginal income function	
	13,305.05/TW	$9.30536/(TW)^{0.197958}$
	Marginal income estimate for each farm (euros (m^{-3}))	
Average	1.52484808	1.62645482
Minimum	1.32490965	1.13684334
Maximum	2.87599483	2.08021579
Standard deviation	0.83114052	0.26683224

Estimated from survey data. Student t-ratio in brackets. Income in euros. TW is total water used.

The estimated marginal income was not significantly related to growers' expressed willingness to pay. Nevertheless, the difference was found to be higher for farms with a greater water availability per hectare (Pearson correlation coefficient equal to 0.54). This could be interpreted as meaning that growers with more water at their disposal are more conservative when expressing their WTP.

Conclusions

The average WTP for water expressed by the tropical fruit growers in the area was €0.27 m^{-3}. The majority were willing to pay between €0.21 m^{-3} and €0.36 m^{-3}. Some of the characteristics influencing this WTP included attendance of training courses and the prompt adoption of technological innovations. Similarly, greater farm area, a larger percentage of avocado trees on the farm, and a higher annual water consumption had a positive influence on growers' willingness to pay.

The average marginal income value estimated for water using the proposed methodology was

€1.52 m^{-3} - much higher than the maximum WTP for water expressed by the respondents. There was a greater difference between the estimated marginal income and the expressed WTP for growers with more water at their disposal, which might indicate these growers made more conservative responses to the survey.

This huge difference between the estimated and growers' expressed WTP raises two important issues (apart from the obvious problems of growers tending to be conservative and giving strategic responses). Firstly, it should be recalled that, for water prices in the range of the WTP expressed by growers, the internal rate of return (IRR) varies between 12 and 14%, as calculated by Calatrava *et al.* (1997). This implies that the growers expressed their maximum WTP for water, which is double or even triple the actual price paid (bearing in mind what they consider to be the minimum acceptable rate of return on their productive activity, which is in fact quite high for agriculture). The second issue relates to the high marginal values estimated for water. The fact that these marginal values are greater than the charges paid by domestic users (double on average) may explain why agricultural activities in the area are still fairly well supplied. It may also explain why urban water utilities rely more on developing their own new sources of supply than on entering into agreements with irrigation districts to buy or lease water rights. Finally, the high marginal value of water suggests that growers could afford to pay for wastewater.

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