PROTECTED HORTICULTURE AND ENVIRONMENT. AN INTEGRAL DECISION MODEL FOR GREENHOUSE WASTE MANAGEMENT IN SOUTHEASTERN SPAIN

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Abstract

Over 380000 tons of vegetable waste is produced annually in the "Campo de Dalías" zone (Almería, Spain), deriving from the diverse existing crops grown under plastic cover). Landfills containing this vegetable waste are a potential breeding ground for diseases and pests, they can also be the subject of uncontrolled burning, cause a riverbed blockage and, at the same time, they are an unsightly aspect of the landscape. The only way to prevent or minimize this problem is to adopt a comprehensive and environmentally sensitive waste management program.

The utilization of the Contingent Valuation Method (CVM) has allowed the monetarization of the total environmental benefit of the projects undertaken, composting plant or in an energy recycling process, to the tune of 4082777 € and 4794566 €, respectively. Likewise, a Geographical Information System (GIS) has been used to locate an optimal zone for a composting plant. The solution obtained minimizes the transportation cost of organic waste. It represents 40% of the total cost at current market price. The subsequent integration of the results obtained with the previous methods in a cost-benefit analysis showed when a decision on possible public action needed to be taken that the best option would be a composting project with a 63.58 million € Net Present Value (NPV), including the internalization in economic terms of the environmental benefit of recycling organic residue. If this benefit is not internalized, the project NPV would be negative.

Key words: Contingent Valuation Method, GIS, Cost-Benefit Analysis.

1. Introducction.

If we bear in mind that the "Campo de Dalías" District (Province of Almería, Southeast Spain) is one of the most intensive horticultural areas in the world, it is hardly surprising that the organic waste from horticultural crops has become one of the most important problems. This has been acknowledged by all the Farmers Associations, Agrarian Syndicates and Public Administrations in the area. In this context, the application of optimization techniques should be introduced to design management systems with minimal crop waste, considering the variety of management processes, such as composting, incineration, landfilling, etc. (Chang et al., 1996). That is to say, decision-makers must consider the economic and environmental costs associated with these alternatives and their applicability to each specific area (El-Fadel and Abou Najm, 2002).

This study was devised specifically with the aim of finding tools to support the decisions that will attain this sustainable management. The starting point was that as farmers are the most directly affected by this problem, it would be necessary to find out their opinion about and willingness to collaborate in the possibility of proposing alternative solutions. For this purpose the Contingent Valuation Method (CVM) was used, a technique employed to assign an economic value to those assets that are not immersed in a market economy (Bräuer, 2003; Osinski *et al*., 2003). As Carson (1991) points out, the attraction of contingent valuation lies on the fact that it facilitates the construction of a market where the researcher can observe an economic decision directly related to the object under consideration.

On the other hand, in a waste management system, one of the most restrictive aspects is the cost of transportation from the place of origin to the treatment plants. In this case we used the potential for spatial data management and analysis of an information technology program such as GIS (Geographical Information System). The objective was to use the GIS technology to find the optimum location for a composting plant for residue; which required minimal transportation costs. Finally, a Generalized Cost Benefit Analysis (GCBA) was carried out where the results obtained were integrated using both of the above mentioned tools (Tiwari *et al.*, 1999).

2. A brief description of the current problem caused by the generation of green waste in Southeastern Spain.

Nature has always been capable of absorbing all the residue derived from farming since the beginning of time. However, when waste concentration goes above certain limits the balance can be distorted, as it can happen when farming becomes more technological. Why has this situation arisen in the Campo de Dalías District? This is fundamentally due to two reasons: on the one hand, the rapid growth of the area, which has gone from 0 hectares of greenhouses to 16000 in 30 years with a spectacular increase in horticultural production (mainly peppers, tomatoes, cucumbers, green beans, marrows, aubergines, melons and water melons), reaching an annual production level of 2.5 million tons. This represents 5% of the EU total production and 21% of the production in Spain. At the same time, the amount of residue generated has also increased in proportion to this (Figure 1) reaching the annual level of 380000 tons. On the other hand, the community, state and provincial legislation have not considered vegetable waste residue as such or at least they have dealt with this matter in a fairly ambiguous fashion, until the Law of Residues of 1998 (Spanish Government, 1998) was issued, specifying that the waste listed in the European Catalogue of Residues (European Commission, 1994) approved by the Community Institutions will be considered as such.

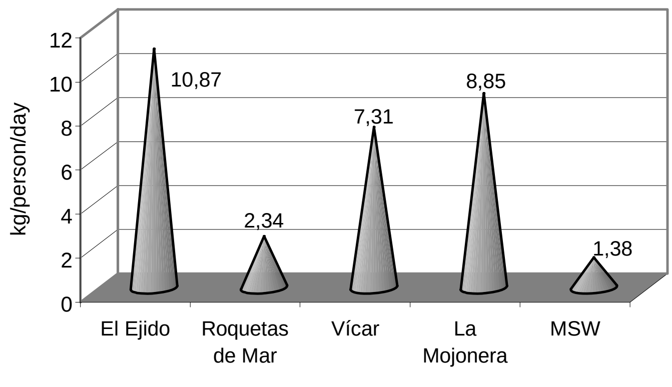

Fig. 1. Residual biomass generation from horticultural crops in the main towns. Comparison with municipal solid waste (MSW) rate.

The traditional way in which farmers have eliminated farming waste has been to abandon it in dry ravines or empty lots. The most important problems associated with this practice are the breeding of diseases and pests, uncontrolled burning, blocking of riverbeds, poisoning of cattle and sheep and its negative visual impact on the landscape (Parra et al., 2001). All these problems can be a threat with regard to atmospheric contamination, human health hazards and deterioration of commercial relations.

3. Objectives.

The main objective of this study is to analyze the viability of two alternative projects for recycling vegetable residue with the application of a cost-benefit analysis and the inclusion of environmental benefits estimated by contingent valuation. The projects chosen were the following:

Alternative 1. Compost production from organic waste generated by protected horticulture.
Alternative 2. Generating energy from the combustion of organic residue and its subsequent use in the desalination of sea water for the irrigation of crops.

From this analysis, the administration (local and central government) must search for optimized regional vegetable waste management planning to attain a successful strategy. Thus, the role of scientists must be to develop useful tools to improve the quality of the information managed by decision-makers.

4. General description of the proposed method.

In figure 2 we can see a diagram where the costs and benefits associated with the projects studied are represented.

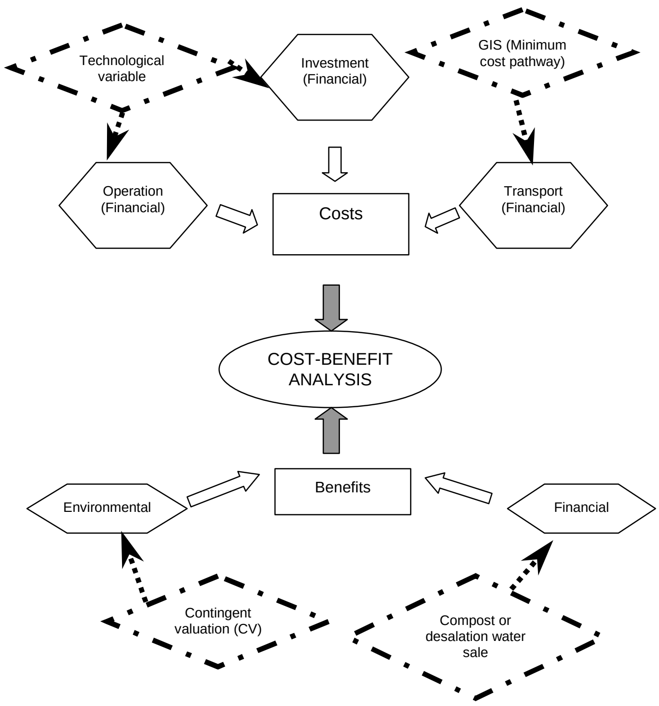

Fig. 2. Cost-benefit analysis diagram of the technological alternatives

Financial costs related to investment and operation will be collected in the budgets of the respective projects and will be evidently linked to the technological infrastructure used in them. In the case of the cost of the transportation required to move agricultural residue from the places where it is generated to the treatment plant, this has been determined using the tools of a Geographical Information System (GIS), the methodological development of which we are about to examine. The financial benefits will be determined by the sale of the output of the recycling plant, compost in the case of alternative 1 and desalinated water in the case of alternative 2. Political and social matters could influence how the sale price is set, as investments carried out with public funds are considered. The contingent valuation method developed somehow express the net environmental benefit of the project in question into monetary units (measuring social well being in money). That is to say, it would give us directly the differential between the benefit minus the environmental cost, which is known as environmental cash flow.

4.1. Contingent Valuation Method (CVM) for including environmental externalities.

Although the origins of this method can be traced to the beginning of the 1960s (Davis, 1963), it became internationally recognized following a report carried out in 1993 by world experts in economics (NOAA, 1993), which was commissioned specifically after the ecological disaster caused by the Exxon Valdez oil tanker in Alaska, as a necessity to assess the environmental damage caused by it.

The design of the hypothetical market constructed seeks to estimate in monetary units the amount that one would be willing to pay to eliminate the vegetable waste derived from horticultural production in the western Almería district. This valuation is interesting since it is the only way to detect the “environmental awareness” of farmers and their need to solve the waste problem. It is through the construction of a hypothetical market that they have the possibility to declare their “Willingness to Pay” (WTP), differentiating between the simple elimination of waste (WTP1) and its recycling according to one of the two alternatives proposed in section 3 (WTP2).

The description of an asset as a valuation object was carried out using an informative booklet, where farmers were shown objective and clear information on the problem of residue and on the two recycling alternatives: composting and generating energy to desalinate sea water for its potential use in irrigation systems. The design of the questionnaire used in the interviews was structured in a series of blocks including opinion questions on the problem of residue and on farming in the area in general, questions on the willingness to pay and on the socio-economic characteristics of the farmers interviewed. The size of the sample chosen was of 242, out of a total population of 9000 farmers.

4.2. Spatial analysis using GIS for the optimal location for the green waste treatment plant.

In this study, we started from the digital map of the region (TIFF format) at a scale of 1:10000 from the Autonomous Community of Andalusia (MTA, 2000), on which greenhouses (waste generating areas) were digitalized in vectorial format as well as a series of restricted zones where the recycling plant should not be located (towns, protected places, roads, ravines, etc.). This digitalization process was carried out in a CAD environment (AutoCad 14™) and the classification of the different features obtained in layers or covers allowed us to import the basic vectorial cartography into a GIS environment, specifically the IDRISI32™ software (Eastman, 1992).

Multicriteria decision methods (Voogd, 1983; Powell, 1996) have been developed in the last decades to provide the user with the means to determine new attributes that indicate alternative responses to problems involving multiple and conflicting criteria. Because these evaluation methods have been fully integrated in GIS (Carver, 1991; Ceballos and López, 2003), to the extent of becoming characteristic of the GIS technology (Burrough and McDonnell, 1998), they were utilized in the study of an optimal location for a composting plant to treat the vast amounts of organic crop waste from the Dalías District. The multicriteria perspective used in our work was based on the suitability of the area to house the compost plant, whilst at the same time minimizing transportation costs (Parra, 2004).

Once the final cost map had been computed, the IDRISI32™ module “Pathway” was able to assess what is known as the lowest cost route for the transportation of vegetable waste between two geographical points. This is simply to determine the least costly network outline for transferring vegetable waste from each production zone to the location of the proposed solution of the composting plant, which will allow us to determine the annual cost of transportation employing equation 2:

$$C = \sum_{i=1}^{K} N_i . D_i . c \qquad \text{(Equation 2)}$$

C being the total annual cost (€), K the number of waste production zones (91 in our case), N_i the number of trips from the ith waste production point to the treatment plant via the minimum cost route, D_i the distance (Km) between the ith waste production point and the treatment plant and c the unitary transportation cost (€/Km). N_i will be calculated using equation 3:

$$N_i = \frac{S_i R}{Q} \qquad \text{(Equation 3)}$$

where S_i is the area of the ith production zone (Has), R is the rate at which vegetable waste is generated (Ton/Ha), around 20.44 Ton/Ha in our case, and Q is the loading capacity of the truck (Ton).

4.3. Generalized Cost Benefit Analysis (GCBA).

This will include the monetary results obtained with the above mentioned tools and will be applied to each of the technical solutions studied: composting and energy generating. The indicator used to apply the GCBA is the Net Present Value (NPV). It is the typical indicator to measure the cost effectiveness of any type of investment. It consists simply of comparing the profits and costs generated by the project, bearing in mind the total cost of the investment and bringing them up to date according to the type of interest through the life of the project. The fundamental difference with regard to the cost analysis in private investments is that the Discount Social Rate (DSR) is used in the GCBA, calculated from National Accountancy indicators and not from the market interest rate. Likewise, the environmental benefits are included in the profits estimated by the CVM (Equation 4).

$$NPV = \sum_{t=0}^{T} \frac{(B_t - C_t)}{(1+r)^t} - \mathrm{K} \qquad \text{(Equation 4)}$$

NPV being the Net Present Value (€), T the project life (years), B_t the benefits per year t including transportation costs estimated by GIS (€), K the investment cost (€) and r the Discount Social Rate. The DSR value was calculated from the product of the variables “consumption growth rate by person” and “elasticity of the consumption marginal utility” (Azqueta, 2002).

5. Results and discussion.

In Table 1 we can see a summary of the results of the willingness to pay and its comparison with the existing market price at the time of the survey. An important aspect to note is that the willingness to pay is above the market price, which once more coincides with the economic theory and gives credibility to the methodology used. WTP1 (landfill option) is 54% higher than the market price, whilst WTP2 (recycling options) is 81% higher than the market price. In any case, bearing in mind these percentages, one could consider the possible existence of what is known as hypothesis bias (Carson, 1991; Frykblom, 1997): given the merely hypothetical nature of the situation faced by the person (how much would you be willing to pay?), this would have no incentive to elicit a correct answer. After all, we are working with a hypothetical approach and thus, errors have no apparent consequences. However, it is necessary to point out that even when our approach is hypothetical, we must not forget that the farmer is already paying to have his waste removed, which inevitably gives the valuation scenario a good dose of realism. To this we need to add that the problems of vegetable waste and the search for a solution have been and still are an ongoing issue with regard to agriculture, both in the press and in any other forum in the district, and that the vast majority of solutions suggested include an economic contribution by the farmers.

Table 1. Willingness to pay of farmers for waste management. Comparison with market price. (WTP 1= Landfill alternative; WTP 2= Compost or combustion alternatives). Note: The real market price at the region presents a value around 144.24 € ha^{-1}.

	WTP 1 (€ ha^{-1})	*WTP 2 (€ ha^{-1})*	
		Compost	*Combustion*
Average	221.68	245.83	288.69
Median	210.35	225.38	240.40
Coefficient of variation	50.58%	52.41%	55.43%
Maximum	901.52	601.01	1202.02
Minimum	0	60.10	60.10

The value of “Environmental Benefit” has been estimated from the WTP2 obtained, by multiplying their value by the number of greenhouse hectares. This “Environmental Benefit” is estimated at 4082777 € for composting and 4794566 € for the recycling of vegetable waste into energy and its subsequent use for the desalination of sea water.

Once we have established the exact location for the treatment plant, we can calculate the minimum cost routes between this and the 91 waste generating zones considered. In Table 2 we can see the descriptive statistics of the annual transportation cost for each of the 91 optimal routes, as well as the total cost. In the case of the desalinating plant, as its location is already defined in the technical preliminary plan, the cost of transportation is higher than that of the solution obtained by GIS. The waste generating rate (R) is 20.44 Ton/Ha. The loading capacity of the type of truck utilized by the different vegetable waste removal and transportation firms in the area is 5 Tons. The unitary cost of transportation is 1.20 €/Km, taking into account the official data supplied by the Spanish Development Ministry (2003) is 1.20 €/Km.

As can be observed in Table 2, the total cost of transporting the vegetable waste to the composting plant is 1004966 €. It is interesting to compare this theoretical result with the actual transportation fee charged at present by the numerous private firms operating in the region. In the second case, we start from an actual market cost of around 36 € per trip for a 5 ton capacity truck, regardless of the distance to the disposal area. Thus, taking into account a vegetable waste production rate of 20.44 Ton/Ha and a total of 16607 hectares of greenhouses in the region, we obtain that the actual transportation cost would be around 2444129 €. Consequently, the utilization of GIS technology to carry out the integral planning of vegetable waste removal from the different production zones (concentration of greenhouses) to a composting plant, would mean a reduction in transportation costs close to 60%. These results appear to indicate that GIS technology can be used as a tool for planning the optimal location for waste treatment plants in an economic and environmentally sustainable way.

Table 2. Transport cost. Statistical parameters

	Compost	*Combustion*
Number of pathways	91	91
Length of the minimum pathway (m)	1028	2278
Length of the maximum pathway (m)	28869	30639
Length of the average pathway (m)	13445	14404
Standard deviation (m)	7112	6164
Annual Total Cost (€)	1004946	1189577

Applying the cost-benefit analysis proposed in Figure 2, a comparison is carried out of the two technical projects proposed. For this purpose, we shall use the cost and profit data with the highest probability, taking into account the information gathered in the existing studies and projects, as well as the results obtained with GIS (waste transportation costs) and the valuation of environmental externalities (contingent valuation) respectively. This comparison will in turn be contrasted with the zero option or reference scenario as it is called, represented by the public initiative known as Zero Sweeping. What did Zero Sweeping consist of? Given that the Rural Hygiene Plans of the different local Councils had not succeeded in cleansing the countryside, the autonomous Andalusian administration set in motion a plan for integral cleansing, put into practice in the summer of 2001 and named Zero Sweeping. In any case, the final destination of the waste collected was the dumping place, and recycling was not considered. Although the commitment of the various Councils was to maintain this cleanliness and not to allow the accumulation of vegetable residue, the fact is that problems appeared again in the latest agricultural seasons. A summary of the parameters we are going to use can be seen on Table 3. The DSR of 2% was used having into account the results achieved from the proposed methodology, considering 1996-2000 period, where values from 1.63 to 3.22 were obtained. This result is according to Weitzman (2001), where, from the opinions expressed by more than two thousand expert economists worldwide, divides the future in five great periods. The referred work assigns a DSR of 2% to the 26-75 years period, indeed where the evaluated projects would be fitted.

Table 3. Cost-Benefit Analysis parameters of technical projects. Comparison with “Zero Sweeping” option. [1]Sale price of desalinated water for crops irrigation (Combustion option) or compost market price (Composting option)

Parameters	***COMBUSTION***	***COMPOST***	***ZERO SWEEPING***
Investment cost (M€)	152.24	6	-
Project life (years)	30	30	30
Annual capacity (t)	340000	340000	283000
Annual production[1] (m^3 or t)	20000000	136000	-
Annual operational cost (€)	5072542	1431400	3972209
Annual transport cost (€)	1189577	1004946	-
Market price[1] (€ m^{-3} or € t^{-1})	0.36	12	-
Annual environmental benefit (€)	4794566	4082777	-
Discount social rate (%)	2%	2%	2%

When the environmental benefit was not included in the evaluation of the public investments examined, a negative value of the NPV of the projects was always calculated. However, when this benefit was included, the NPV became positive in the composting plant project and reached a value of 63.58 million €. Thus, the NPV experienced an increase of 328%. In the desalinating project the increase was 84%, although the NPV continued being negative. Bearing in mind that, from a social point of view, the environmental benefit must be included in the analysis, it is evident that any of the two alternatives is much more advisable than the Zero Sweeping option. The choice between the two alternatives favors composting, in view of the results obtained for NPV. Although the desalination plant presents throughout the project life positive cash flows for the parameters considered in the analysis, it can not compensate for the high cost of the investment.

6. Conclusions.

Although the contingent valuation method is widely criticized from an ethical point of view, which considers that a market value should not be assigned to certain natural goods, it seems that there is a greater consensus in acknowledging that it can be very useful to value negative environmental externalities, mainly if their temporary effects are not very prolonged. These opinions support the hypotheses used in this study, where the actions of the projects (utilized in the hypothetical market on willingness to pay) eliminate short-term environmental impacts. The validity of the contingent valuation method is ratified to simulate reality in the case of assets subjected to market discipline but with a strong environmental component.

The utilization of a GIS from secondary cartographic information and of the estimation of vegetable waste generation in the greenhouses of the Campo de Dalías District (Almería), has allowed the location of an optimal zone to install a composting plant to recycle the above mentioned waste, bearing in mind the environmental restrictions which have been deemed most determining. Likewise, the utilization of the GIS has permitted us to determine the minimal cost routes between the optimal location of the composting plant and each one of the waste generating zones.

The introduction of the contingent valuation method, together with the spatial analysis (GIS) in the development of the cost-benefit analysis, can be a very valuable tool to support decision making with regard to investment in public projects of these characteristics. The awareness of these problems and their possible solutions based on the methodology used can be extrapolated to other areas where the development of crops grown under plastic cover is starting to become greatly important.

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