

COST BENEFIT ANALYSIS OF THE USE OF RECLAIMED WATER IN AGRICULTURE

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ABSTRACT

The European Water Framework Directive (WFD) prescribes that all water bodies in Europe should achieve the “good ecological status” (GES). Maintaining a certain water flow is a pre-condition for the achievement of the GES in areas of water scarcity, where the pressure over the resource imposed by the different water users (agriculture being the most important of them) is already very high. This pressure can only increase in the future due to climate change. In this context, the reuse of treated water for agricultural irrigation is considered a promising option and there is an increasing number of reuse projects going on in southern European countries. As part of assessing the viability of reclaimed water use in agriculture, and in line with the economic principles underpinning the WFD, a comprehensive economic analysis of this water management option is still needed. The aim of this paper is to contribute to filling this knowledge gap by producing a full cost-benefit analysis (CBA) of the use of reclaimed water in agriculture in the specific context of the WFD. For this purpose, we undertake a case study in the Segura River Basin, in southern Spain, where the costs of reclaimed water use in an experimental farm producing mandarins are compared with its benefits. The novelty of this study is that we also incorporate non-market benefits (obtained with the use of a stated preference approach) as the welfare improvements obtained by general public due to a more sustainable use of water to ensure the provisioning of environmental services. This type of “intangible” benefit is often ignored in economic analyses, due to the difficulty of its estimation and the hypothetical nature at the basis of the assessment methods available. However, only the combination of market and non-market costs and benefits can, in line with economic theory, produce a balanced assessment of water management options leading to an efficient and sustainable allocation of the resource.

1 INTRODUCTION

Water is a vital natural resource, which is becoming increasingly scarce around the world. Unsustainable water management has led to crisis situations in certain regions, where the relation between water availability and demand has reached critical levels. Water shortage will be even more pressing in future due to climate change and the resulting decrease in precipitation, increase in the frequency and intensity of droughts, and probable increase in the demand for irrigation (IPCC, 2007). Dealing with water scarcity is therefore one of the major water policy challenges for the future; one that moreover requires the supply of water for productive uses to be made compatible with environmental protection. In this context, agricultural water management is one of the main challenges due to agriculture being main water consumer in most water scarce regions.

In the European context, the WFD came into force in 2000 and represents an important opportunity as well as a major challenge for water management. The objective of the WFD is the achievement of the GES in all European watersheds.).

To achieve the ecological objective, the WFD prescribes the use of economic principles and tools. The Directive requires the Programs of Measures (PoMs), which consist of the combined measures to attain the GES, to be drawn up according to economic principles. Also, derogation requests the environmental objectives to be justified on the basis of an economic analysis, proving the costs of implementation are not proportional in relation to the benefits (Article 4). Finally, Members States have to pursue cost recovery of water services, including environmental and resource costs (Article 9).

Although water quality has been seen as the major focus of the WFD, quantitative aspects, i.e. flow levels, are an essential part of the definition of the GES in the Directive and the allocation of enough water to the environment to ensure a certain flow of water is a pre-requisite for its achievement (Martin-Ortega et al. 2011). Thus, in water scarce regions, the reuse of treated water is considered a promising measure to mitigate the effect of water shortages (Alcon et al. 2010; and 2011). It is being promoted across Europe and is seen as an opportunity to sustainably expand supply in the face of increasing droughts and water scarcity (EEA, 2009).

Reclaimed waste water is defined in Spanish legislation as water rendered fit for reuse (BOE, 2007), and five different settings for this reuse are identified: an urban, agricultural, industrial, recreational, and environmental one (Iglesias and Ortega, 2008). However, it can also have a non-consumptive use, sometimes called “indirect reuse”, when it helps to maintain a sufficient water flow. In this case study, we focus on the latter: ‘environmental’ use of the water, as it can contribute to the achievement of the GES under water scarcity conditions. In this way, the use of reclaimed water could be an appropriate measure to be included in the PoM, and consequently contribute to achieve the GES of WFD.

As part of assessing the viability of reclaimed water use in agriculture, and in line with the economic principles underpinning the WFD, a comprehensive economic analysis of this water management option is pending. The aim of this paper is to contribute to fill this knowledge gap by producing a full cost-benefit analysis (CBA) of the use of reclaimed water in agriculture in the specific context of the WFD. To achieve this objective, the costs and the benefits derived from the use of reclaimed water in an

experimental mandarin plot in the region of Murcia (South-East of Spain) are compared. The study uses data collected during the 2008-2010 period, extending it later on the basis of estimations throughout the life of the mandarin trees, thus achieving a more general approach.

The novelty of the study is that it also incorporates non-market benefits (obtained with the use of a stated preference approach) as the welfare improvements obtained by the general public from a more sustainable use of water to ensure the provisioning of environmental services. This type of “intangible” benefit is often ignored in economic analyses, due to the difficulty of its estimation and the hypothetical nature underpinning the assessment methods available. However, only the combination of market and non-market costs and benefits can, in line with economic theory, produce a balanced assessment of water management options leading to an efficient and sustainable allocation of the resource.

2 CASE STUDY DESCRIPTION

The case study is located in the Segura River Basin in the Spanish south-eastern region of Murcia. In this region, agriculture occupied 565,143 ha in 2007, from which 188,534 were irrigated. The main types of irrigated crops are vegetables (42,571 ha), citrus (38,767 ha) and other fruit trees (27,202 ha) (CARM, 2008). According to the Regional Ministry of Water and Agriculture, the annual volume necessary to cover the agricultural water needs of the area exceeds 880hm³ (CARM, 2007).

The Segura River Basin has a water exploitation index of more than 130%, making it the river basin with the third highest level of water stress in Europe (EEA, 2009).

The resource scarcity in the source basin has generated an almost permanent undersupply in this area. This scarcity is aggravated by the population growth, the dry seasons of recent years and the scarce annual rainfall (280 mm/year), so that the water availability to the farmer is surrounded by an uncertain environmental and political context. Farmers in the study area are supplied mainly by surface waters coming from the Tajo River, in the middle of Spain, which is routed through a system of channels to the Segura Basin. Variable and insufficient allocations have led many farmers to use groundwater and reclaimed water to make up shortfalls in supply.

The reuse of treated water in the region of Murcia, South-East of Spain, has risen significantly in the last decade. The current annual volume of treated waste water, generated in 96 wastewater treatment plants in Murcia, is 101.8 hm³ (ESAMUR, 2010), which is equal to a sixth of the total renewable resources of the basin. Besides serving other purposes, treated waste water currently supplies 12.8% of all irrigation water in the area. Given the water shortage in the region, the use of reclaimed water for supplying irrigated crops has important economic and environmental implications.

3 MATERIALS AND METHOD

3.1 Materials

To perform this CBA, we used the parameters recorded during 2008-2010 on a farm during located in Molina de Segura, Murcia (38 ° 07'N, 1 ° 13'W), of nine-year-old mandarin trees (*Citrus Clementina* L. cv. “Orogrande”) grafted onto Carrizo Citrange (*Citrus sinensis* x *Parcisis trifoliata*) with a plant spacing of 5 x 3.5 m. After their

plantation trees were watered by drip irrigation from a single lateral row of trees and three drippers per plant, 4 l/h. During the study period, irrigation was scheduled weekly using the Penman-Monteith equation (Allen *et al.*, 1998) and the monthly crop coefficient (Castel *et al.*, 1987) according to climate data recorded in Campotejar.

Three different treatments were carried out on the farm depending on the specific use of waters of different origin and quality. One of the regimes applied irrigation water from the Tajo-Segura river diversion ($EC \approx 1 \text{ dS m}^{-1}$), a second regime used water from the Campotejar Irrigation Community, comprising a mixture of surface water, groundwater and purified water ($1 \leq EC \leq 3.5 \text{ dS m}^{-1}$) while the third regime involved irrigation with water from EDAR de Molina de Segura Norte ($EC \approx 3.5 \text{ dS m}^{-1}$). The water used in the second treatment is of variable quality depending on resource availability (Tajo-Segura diverted water, groundwater and reclaimed water) and on the intensity of crop evapo-transpiration requirements.

For all treatments common cultural practices were followed for commercial citrus plantations in terms of fertilization, weed-control and pesticide treatments. Final yield was also monitored over the three-year study period.

3.2 Cost-Benefit analysis

Cost-Benefit Analysis (CBA) is a decision-making usually used as a decision criterion in public investment evaluation (Vining and Weimer, 2010) and probably the tool most commonly used to evaluate environmental policies, projects or investments. It is used to compare the costs and benefits of a given policy, initiative or investment; including the costs incurred and profits obtained by the promoters of an initiative (private component), but also by the rest of society, i.e. the external/collateral costs and benefits (social component). Thus financial CBA would consider only market cost and benefit, while social CBA would consider both market and non-market cost and benefits¹. Social CBA includes social profitability criteria because this aspect is evaluated in terms of the increase or decrease in global welfare, and hence criteria involving intergenerational equity and sustainability can be incorporated (Hanley and Spash, 1993).

When CBA is applied, six general stages should be fulfilled (Martínez-Paz *et al.*, 2011):

1. Identify all the costs and benefits.
2. Value costs and benefits in monetary units.
3. Establish the time horizon of the evaluation.
4. Fix the discount rate.
5. Make selection and profitability indicators.
6. Conduct a sensitivity analysis of indicators to the variables of the most uncertain value.

3.3 Cost analysis

The cost analyses distinguish between investment and operational costs. Investment costs are related with the value of the initial investment that enables activity start up, while the operational costs correspond to the cash flow necessary for a proper running

¹ Some authors use the term Classical CBA when they consider market cost and benefits and Extended CBA when they consider both the costs and benefits of the market and non-market ones.

and development.

In our study, initial investment for a mandarin crop includes the cost of both the labour and the assets needed to set up the plantation: the soil, the plantation, the drip irrigation technology, the reservoir and the machinery. Considering an average farm area (5 ha) the investment costs have been estimated in €115,375.

The method used to estimate operational costs looked at the total cost of production (Caballero *et al.*, 1992): the variable costs generated as a function of the inputs used, the opportunity cost and the fixed costs faced by the grower related with the initial investment. This provides the net profit and permits retrieval of all the factors involved in the production process and, therefore, the capitalization of the farmer.

The variable cost includes all inputs used in the annual productive process. This concept comprises raw materials, such as water, fertilizers, and plant pest control products, as well as machinery costs and manpower. Water tariffs are established by the irrigators' association and depend on the water source.

Water resources from the Tajo-Segura river diversion have an average price of 0.31 €/m³. The price for farmers of the second water treatment analysed (mixture of water from different origins) was of 0.32 €/m³. Meanwhile, the third treatment assayed in the study was the exclusive use of reclaimed water, with a corresponding price equivalent to the costs of carrying it to the plots, estimated at an average of 0.20 €/m³. The schedule for irrigation, fertilizer application and pesticide treatments were established by agricultural technicians and farmers themselves, depending on the point in each of the campaigns. In addition, labour needs, both own and outsourced, were checked by the District Agricultural Office in the area, adjusting wages to average wages for the area under study.

Fixed costs include the set of factors that do not comprise a single production process alone but can be used in subsequent periods. This concept includes the fixed costs of machinery (such as depreciation, insurance, storage and repairs), amortization of plantations and facilities, and taxes and insurance. To estimate fixed costs we have considered the usual taxes for a farmer with an average holding of 5 ha of citrus with 80% of the crop insured, which has an irrigation capacity according to farm size and a 72 hp tractor and a 1000 L spray tank. This is the most frequently found machinery park scenario among producers in the area.

Finally, the opportunity costs comprise the interests of fixed and variable capital and land income.

3.4 Benefit analysis

To quantify the benefits of using reclaimed water for agriculture it is necessary to distinguish between the private and social benefits.

The private benefits depend on the yields obtained and their sale prices. Prices received by farmers for use in the analysis, are officially published by the Spanish Ministry of Agriculture and Water in the Region of Murcia (*Consejería de Agricultura y Agua de la Región de Murcia* - CARM, 2011). Meanwhile, production depends on the irrigation strategy used.

As regards the social benefits, the use of reclaimed water for irrigation causes a positive externality on society, since the use of reclaimed water for irrigation involves environmental benefits beyond market benefits. Non-market benefits are related to non-use values associated with preserving the ecological status of the watershed, with the

value of indirect use of locally grown produce, and the use of labour in irrigated fields with water generated in the area (Birol et al. 2010).

For the Segura river-basin, where conventional water resources are scarce, Alcon et al. (2010) used the contingent valuation technique to estimate non-market benefits that society associates to the use of reclaimed water for agricultural purposes. Their work shows a mean willingness to pay of €5.13 per month per household. Thus, the non-market benefits quantified in terms of water bill amounted to 0.31 €/m³ on average. These are the values that we use for our integrated CBA.

3.5 Profitability indicators

The Net Present Value (NPV), the Internal Rate of Return (IRR) and the Payback Period (PB) are the most commonly used methods to assess profitability. NPV aggregates all benefits (B) and costs (C), given in a certain period of time usually measured in years (t), applied to a discount rate (r), minus the investment cost (K).

$$NPV = -K + \sum_{t=1}^t \left(\frac{B_t - C_t}{(1+r)^t} \right) \quad (1)$$

Where B_t and C_t denote the private cost and benefits respectively and r the usual discount rate.

When environmental costs and benefits are considered and a dual-rate discounting is applied, the NPV is therefore as follows (Almansa & Martínez-Paz, 2011):

$$NPV = -K + \sum_{t=1}^t \left(\frac{B_t - C_t}{(1+r)^t} \right) + \sum_{t=1}^t \left(\frac{B_t^e - C_t^e}{(1+edr)^t} \right) \quad (2)$$

Where the superscript e denotes environmental cost and benefits, and edr the environmental rate of return.

The IRR in the CBA is the interest rate at which the net present value of costs of the investment equals the net present value of the benefits of the investment. Internal rates of return are commonly used to evaluate the desirability of investments or projects. The higher a project's internal rate of return, the more desirable it is to undertake.

The PB period in CBA refers to the period of time required for the return on an investment to 'repay' the sum of the original investment.

4 RESULTS

A detailed analysis of costs and benefits, both private and social, for mandarin growing can be seen in detail in Table 1, for average values of different irrigation regimes used.

Regarding these different irrigation regimes, crops irrigated with water from mixed sources proved to be the most productive (50,566 kg/ha), followed by crops using diverted river water sources (45,625 kg/ha), with the lowest production of the treatments analyzed (37,955 kg/ha) corresponding to the exclusive use of reclaimed water treatment. If we analyse these irrigation regimes in terms of private profits, the differences between them increase. However, if we consider the environmental benefits of using reclaimed water, irrigation using a mixed water source is the most beneficial for society, while the differences between the social benefits arising from the use of

reclaimed water and diverted river water are small.

Table 1: Costs and benefits of mandarin production under three water treatments

	Surface water		Mix water		Reclaimed water	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
1.- PRODUCTION						
1.1.-Yield (kg/ha)	45625	13272	50566	8992	37955	5042
1.2.-Price (€/kg)	0.33	0.00	0.33	0.00	0.33	0.00
TOTAL INCOME (€/Ha)	15056	4380	16687	2968	12525	1664
2.- VARIABLE COSTS						
2.1.- Raw material (€/ha)						
2.1.1 –Irrigation water	1777	199	1835	206	1147	129
2.1.2.- Fertilizers	776	90	776	90	776	90
2.1.3.- Plant protection products	344	224	344	224	344	224
2.1.4.- Others	298	0	298	0	298	0
2.1.5.- Electric energy	420	0	420	0	420	0
Total raw materials (€/ha)	3614	469	3672	475	2984	407
2.2.- Own machinery costs (€/ha)	80	2	80	2	80	2
2.3- labour (€/ha)						
2.3.1.- Irrigation	624	48	624	48	624	48
2.3.2.- Pruning	546	19	546	19	546	19
2.3.4.- Treatment	354	0	354	0	354	0
2.3.5.- Farm works	191	0	191	0	191	0
Total labour (€/ha)	1715	65	1715	65	1715	65
TOTAL VARIABLE COSTS (€/ha)	5409	493	5467	499	4779	426
3.- FIXED COSTS (€/ha)						
3.1. - Fixed costs of own machinery	112	0	112	0	112	0
3.2. – Depreciation of plantation	583	0	583	0	583	0
3.3. – Trees renewal and others fix costs	101	0	101	0	101	0
3.4. –Depreciation of irrigation reservoir	405	0	405	0	405	0
3.5. – Depreciation of others assets	301	0	301	0	301	0
3.6.- Insurance and taxes	247	6	247	6	247	6
TOTAL FIXED COSTS (€/ha):	1707	33	1707	33	1707	33
4.- OPPORTUNITY COSTS (€/ha)						
4.1.- Capital interests of fix capital	472	0	472	0	472	0
4.2.- Land rent	480	0	480	0	480	0
4.3.- Capital interests on current assets	122	11	123	11	108	10
TOTAL OPPORTUNITY COSTS (€/ha)	1048	27	1050	28	1035	26
5.- TOTAL COSTS (VC+ FC+OC)	8165	518	8223	525	7520	448
6. – NET MARGIN	7940	4838	9513	3282	6039	2082
7. – PRIVATE BENEFIT	6891	4847	8463	3280	5005	2102
8. – ENVIRON. EXTERNALITY	0	0	355	40	1777	199
9. – SOCIAL BENEFIT	6891	4847	8819	3261	6782	1903

The different irrigation regimes have virtually the same production costs, apart from the type of irrigation water used and its characteristics, since this is the differentiating factor in the analysis. Similarly, variations in yields can be attributed to water used for cultivation, since the other elements remain constant within each growing season.

To determine whether there are significant differences in average values, an analysis of variance has been made to check the hypothesis of equal means of differentiating factors under the different irrigation regimes studied.

The differentiating elements in economic terms are: the cost of irrigation water, private profit, environmental externalities and social benefits. Table 2 shows the results of the variance analysis, and these indicate there are significant differences between treatments for both irrigation water costs as well as the economic value of the externality.

Therefore, significant differences were observed for reclaimed water as compared to treatments using only water from the Tajo-Segura river diversion or the mixed waters of different origins, commonly used by farmers in the area.

The variance analysis shows that despite the existence of differences in irrigation water costs, yields are not affected significantly when considering both the private and social benefits. The analysis of variance shows that the null hypothesis (i.e. equality of treatment) cannot be rejected.

Table 2: Analysis of economic parameters under three water treatments.

	Surface water	Mix water	Reclaimed water
Cost of irrigation water	a	a	b
Private Benefit	n.s.	n.s.	n.s.
Environmental externality	a	b	c
Social Benefit	n.s.	n.s.	n.s.

— Different letters by row note significant difference according with Tukey test, $p < 0.05$. —

A more extensive CBA has been carried out in order to analyze the profitability of the mandarin crop throughout its whole productive life and the effect of the water regime employed. Also, the effect of the inclusion of environmental benefits related with reclaimed water use in agriculture has been considered. To this end, the time horizon is defined by the useful life of a mandarin crop, which is around 30 years in this area.

The discount rate is intended to represent society's preference for consumption in the present over the future (Henderson and Bateman, 1995). The higher the discount rates are, the higher the preference for present consumption will be, since the benefits to be enjoyed in the present will be more greatly appreciated than those held in reserve for future enjoyment (Gollier, 2002).

Some authors recommend the use of different discount rates for market and non-market costs and benefits, in the same CBA application, given their different characteristics (Kögel 2009; Almansa & Martínez-Paz, 2011). Thus, the use of a dual-rate discounting would allow the consideration of the sustainability and intergenerational solidarity, since it is not compatible with the application of the same discount rate to both market and environmental flows, for the reason that the discount

means to underestimate future generations' preferences (Roumboutsos, 2010, Almansa & Martínez-Paz, 2011). Consequently, the usual discount rate should be applied to market flows, whereas a lower discount rate (an environmental discount rate) should be used in the case of non-market goods (Kula and Evans, 2011).

The European Commission suggests a standard social discount rate of 5.5% (European Commission, 2008). However, this has been considered high and, according to results by Almansa and Martínez Paz (2010), using a Delphi method in Spain, the median value of environmental discount rate applied for an 0-30 years horizon is 3.5%.

According with these parameters, profitability indicators have been developed (Table 3). Considering the whole life of the crop, the water treatment that uses a mix of different water sources is the most profitable, with water treatment of reclaimed water being the least profitable. However, considering environmental benefits of using reclaimed water in agriculture, the NPV of the reclaimed water treatment overcomes the use of surface water alone.

Table 3: Profitability indicators

		Surface water	Mix water	Reclaimed water
Financial	NPV (€)	90,975	166,375	76,357
	IRR (%)	10	13	10
	PB (years)	14	11	14
Social	NPV (€)		171,487	102,368
	IRR (%)*		13	12
	PB (years)		11	13

*IRR has been estimated holding environmental discount rate invariable.

Mandarin prices, highly variable among seasons, are declining in the last decade which is becoming a major issue for farmers, together with increasing water prices. Thus a sensitivity analysis of mandarin prices has been carried out. This analysis demonstrates that the variation in wastewater treatment prices follows a very similar trend to variations in water coming from river diversion and a greater difference when the water is of mixed origin, regardless of whether benefits are private or environmental (Figure 1). In the case of mixed water treatments, profitability is achieved once the tangerine price exceeds 0.25 €/kg. However, when reclaimed water is used, environmental effectiveness is achieved at a tangerine price of 0.26 €/kg, lower than in the other cases.

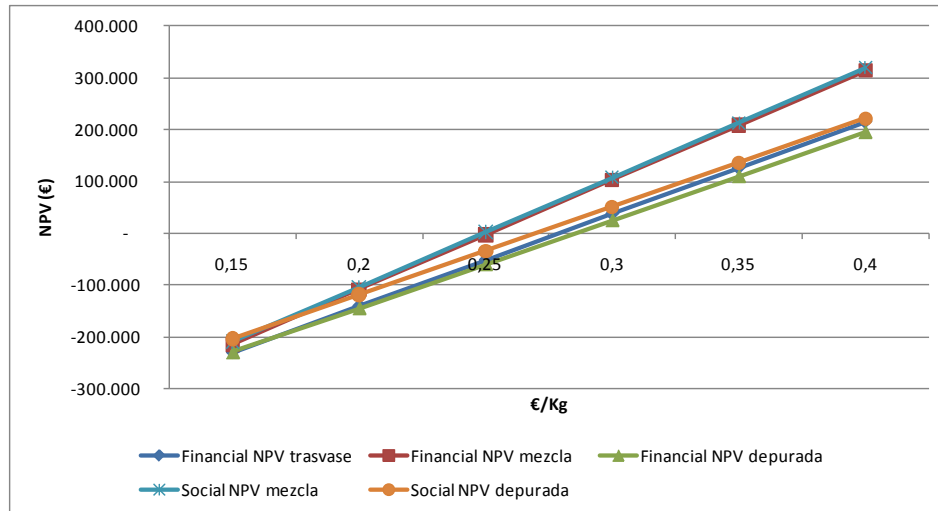


Figure 1: Analysis of NPV sensitivity regarding mandarin sale price per irrigation water treatment

5 CONCLUSIONS

3TA cost benefit analysis (CBA) has been performed for mandarins grown under three irrigation regimes (diverted river water, mixed origin water -a common practice among farmers- and reclaimed water) in the Murcia region in the South-East of Spain. In addition to private benefits, we have considered the environmental benefits of using reclaimed water for agricultural purposes, allowing us to estimate the benefits in wellbeing derived from the cultivation of this citrus fruit.

Our results show significant difference regarding water price. However, when considering both private and social benefits, the differences become non-significant.

Although the yields obtained by using reclaimed water are slightly lower than those obtained by employing conventional water resources, and after considering the environmental benefits as defined by the WFD, the benefits of using reclaimed water to cultivate mandarin crops do not differ significantly from those obtained when conventional resources are used. Therefore, and because the environmental benefits of reuse in water-deficient areas are considerable, from the perspective of the CBA the suitability of these waters is evident.

This study proves that is possible to incorporate non-market environmental benefits into decision-making rules for water planning, as prescribed by the WFD. This example highlights that if those benefits are bias can take place leading to inefficient decisions from the economic point of view.

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