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Social and private costs of water for irrigation: The small desalination plant in San Vicente del Raspeig, Spain

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ABSTRACT

Among non-conventional water resources, desalination (from seawater or brackish aquifers) has emerged as a feasible option to deal with water shortage in arid and semi-arid areas. At the University of Alicante (UA, SE Spain), water availability is lacking and groundwater quality is poor. To ensure water availability, the UA built a small reverse osmose (RO) desalination plant (450 m^3/day) to water the green areas and an urban park on the campus. The costs of a small private desalination plant, landscape irrigation, and the full cost of water, were assessed. This assessment considered the benefits made by new green areas existing in an urban space and citizens' willingness to pay (WTP) for its preservation based on the contingent valuation method (CVM). The results indicated that the final desalinated brackish water cost was 0.29 €/m^3 and, according to the WTP results, the value that derived from the social benefits provided by the leisure area was 0.51 €/m^3, being the final cost of water 0.22 €/m^3. Consequently, the use of brackish water for irrigation has a high social value that should be considered when evaluating desalination-related projects.

1. Introduction

Water scarcity is one of today's most important challenges and constitutes an increasing problem in many parts of the world [1,2]. Around 70% of the world's available resources are estimated to be used for irrigation, which can rise even more in some countries and regions, and exceed 90% [3]. In order to address such increasing water scarcity, alternative water sources for irrigation purposes need to be developed, particularly in arid and semi-arid areas. Among non-conventional water resources, desalination (from seawater or brackish aquifers) has emerged as a feasible option to increase water resources availability. It has also become an extensively applied and sustainable solution for an increasing number of regions worldwide to solve water scarcity problems [4–6].

Furthermore, as the cost of desalination has progressively dropped over the years and conventional water resources have not become easily accessible in many worldwide regions, desalination is now more economically competitive and attractive [7]. This fact has also led to some saline/brackish continental aquifers in south European Mediterranean countries being exploited [8,9].

Economic evaluation project techniques are frequently used to assess desalinated water prices [10]. However, to estimate the full cost of water estimations, it is necessary to include not only supply costs (operation, maintenance, and capital costs), but also other environmental and social costs (e.g. use for landscape irrigation), which are not generally taken into account.

Green areas and urban parks provide significant socio-economic, environmental and health benefits to city residents, and contribute to the quality of life in the urban setting [11,12]. Although an extensive literature assigns green areas and urban spaces for market value valuations based on different techniques and procedures [13–15], the public's "parks and gardens" assets are difficult to evaluate. The most commonly used valuation methods are: travel cost, hedonic prices and contingent valuation. The appeal of these techniques is that they facilitate the construction of a market in which researchers can observe an economic decision directly related to the asset in question [16]. The willingness to pay (WTP) approach for preserving green areas, based on a contingent valuation method (CVM), is a widely used accepted method used to collect data from respondents in their area of expertise. The main feature is that the individual is left only with the problem of deciding if (s)he is willing to pay a fixed sum to access the benefits of the park, lagoon, green area, etc. offered [17–20].

At San Vicente del Raspeig in SE Spain, where the University of Alicante (UA) is located, water is a limiting resource. Its low groundwater quality for irrigation, together with new developments in desalination, motivated the UA to build a small RO desalination plant

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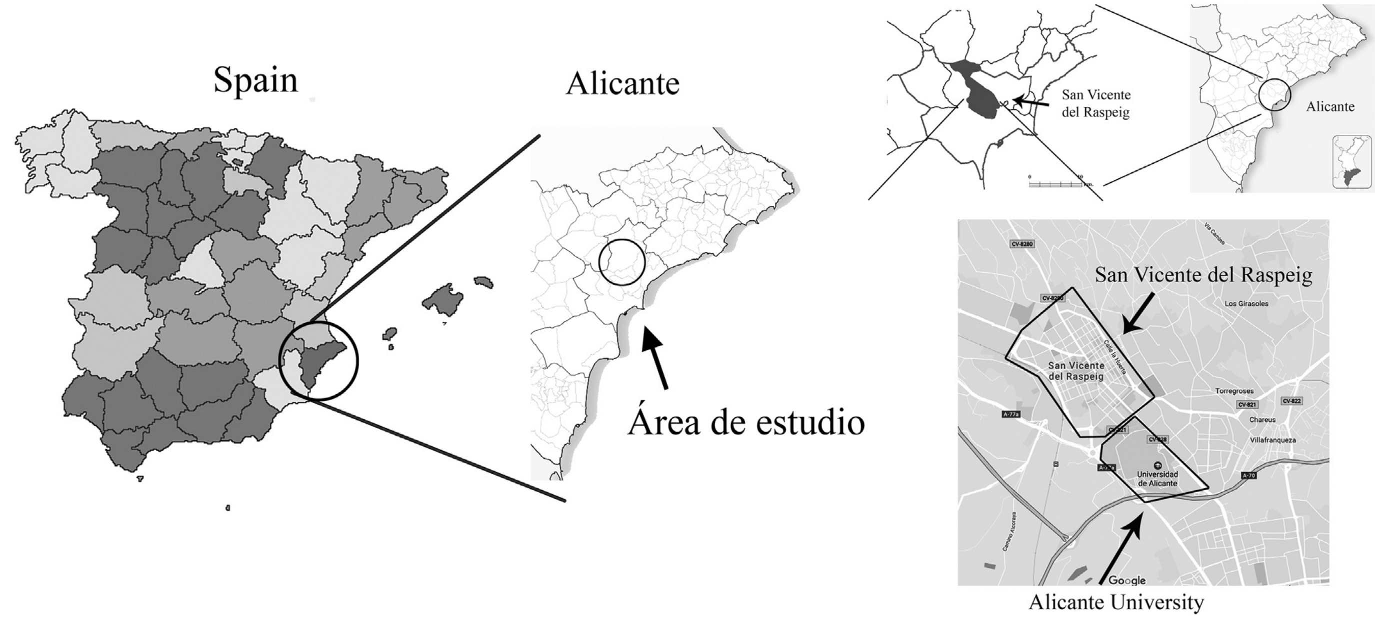

Fig. 1. Study area and the park's location.

(450 m^3/day) to ensure water availability for its green areas, urban park and a lagoon used for desalinated water storage [21]. The aim of this research was to calculate the real value of the desalinated water used on the campus by estimating the monetary benefits that arise from the UA's green area irrigation, lagoon and urban park maintenance, and to evaluate the impact on citizens' WTP to preserve it.

For this research, a methodological framework for the private cost calculation of the small RO desalination plant was firstly obtained; secondly, a contingent valuation method, (CVM), using a Delphi methodology based on a questionnaire approach, indicated the hypothetical maximum WTP to preserve the lagoon, the green area and the park used.

2. Study area

This study focused on the San Vicente del Raspeig area (Alicante, SE Spain; Fig. 1). Characterised by a semi-arid climate and low precipitation (300 mm/y), rainfall is most irregular, and half the annual precipitation can easily be obtained in just a few hours [8]. This area has had severe drought problems in recent years.

The UA campus covers approximately 30,000 m^2 of irrigated garden areas with lawn, ornamental plants and trees. This area, and especially the urban park, has had a socio-economic and environmental impact on the zone. Faced with a growing campus and water needs, and having to consider water scarcity, a solution was sought by the RO desalination project of continental brackish groundwater from the underlying quaternary aquifer. Presently, the landscape is irrigated with a mixture of desalinated brackish groundwater and raw water from the aquifer [21].

Aquifer matter comprises silty sandy materials with some clays overlying the impervious loam materials of Cretacic origin. The geology of the region is rather complex, which includes the presence of some outcrops of gypsum, which lead to poor groundwater quality. Electric conductivity values above 6000 μS, and SO^4, Cl and Na concentration of around 1800 mg/l, 1500 mg/l, and 1200 mg/l, respectively, are quite common.

Between 1997 and 2014, the plant has replaced 1,900,000 m^3 of drinking water by desalinated water and brackish well water. The facility has led to significant economic savings and has allowed the use of water resources that were previously unusable due to the high natural salinity.

2.1. The University of Alicante brackish water desalination plant

Initially set up for academic purposes, the RO plant is fed with water from a 33 m deep well pumping the brackish aquifer. Desalted water is conveyed to a pond where is stored and blended with raw groundwater from a second aquifer pumping well located in campus. The proportion of groundwater and desalted water mix ranges between 5% for winter and 22% during summer. Rejected brines are conveyed to an ephemeral creek.

Initial design of treatment capacity was 450 m^3 day and 72% of conversion capacity. Currently, the desalination plant produces 351 m^3/day of permeate, and 63% of conversion. There is a single treatment line with a total of 25 membranes distributed in two stages (15 membranes in the first stage and 10 in the second). The membranes used are spiral-wound, aromatic polyamides arranged in modules supplied by Hydranautics (8040~UHY-ESPA). The working pressure is 12 kg/cm^2. It is important to point out that there is a variable frequency incorporated into the plant that controls the operation of the high-pressure pump.

The pre-treatment consists of a filtration system with sand filters and cartridge filters, with a continuous application of 3.8 mg L^{-1} PERMATREAT191 antiscalant, and finally the water produced is conveyed to an accumulation deposit with a capacity of 500 m^3. After desalination and $Ca(OH)^2$ addition for a pH increase, water is finally stored in the accumulation deposit (pond) with a capacity of 500 m^3 prior to being used in campus irrigation. For an extensive information regarding the facility, the reader is submitted to [22,23].

3. Data and methods

The followed procedure was based on the collected data and included two steps: private cost calculation of desalinated water and applying the contingent valuation method (CVM) to the obtained cost to assess the final price.

The amount of irrigation water applied to green areas and the park, 148,500 m^3/yr, was provided by the personnel in charge of the operational UA desalination plant.

For social data collection purposes, no face-to-face interviews were conducted. Instead 40 questionnaires, followed by telephone interviews, were sent by Email to selected residents and to UA personnel (known as a panel of experts) in spring 2017. The questionnaires were