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Economic evaluation of small desalination plants from brackish aquifers. Application to Campo de Cartagena (SE Spain)

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1. Introduction

In recent years, the Mediterranean area has witnessed an increasing water shortage trend, mainly due to: increasing population and tourism (especially in coastal areas), new agricultural developments, decreased rainfall and water management issues [1]. In some Mediterranean areas, precipitation is lower than 300 mm/year; the temporal variability of precipitation controls and affects both the quantity and quality of water resources, and is a source of freshwater availability inequalities. Droughts, as a result of temporal precipitation irregularities, are common in all areas and lead to lack of temporal water resources [2].

In a number of Mediterranean basins, one of the main challenges is to secure a reliable water supply in both quantity and quality terms in order to guarantee sustainable use and enough resources, even during long inter-annual dry periods [3]. In Spain, some technical and non-technical solutions proposed for the different Basin Plans [4] range from water transfers, public participation, economic measures, water saving, aquifer recharge, the development of new water supply sources (as seawater/brackish water desalination) to a more flexible water management system implementation according to Integrated Water Resources Management (IWRM).

Desalination (from seawater or brackish aquifers) has generally become an extensively applied solution for an increasing number of regions around the world and is considered one of the most sustainable solutions to the water scarcity problem [5–7]. In recent years, the advances made in Reverse Osmose (RO) technology have been such that this technique is being used in almost all new plant designs being constructed worldwide. Seawater desalination costs remain high and they have been rarely considered for agricultural purposes, except for highly profitable crops and greenhouses [8]. However, continuous technological development, along with improving energy consumption, have increased the building of private small brackish water desalination plants [9].

In comparison with seawater [8], brackish water has lower dissolved salts, which makes the life span of membranes longer. As a result, this has led to the exploitation of saline continental aquifers in southern European Mediterranean countries [10] particularly in Campo de Cartagena (the Segura Basin) in southeast Spain. Campo de Cartagena is one of Europe's driest areas (precipitation around 300 mm). However, given the high quality of land and its mild climatic conditions, it has excellent aptitudes for very competitive agriculture, devoted largely to exports and to domestic food supplies [11]. As water availability is lacking and groundwater quality is poor, which impairs its direct use for irrigation, the agricultural sector has developed private small groundwater desalination plants (15–20 m^3/h) to ensure water availability for its crops [12]. This agricultural management is most relevant in the region, mainly due to the continued growth of these facilities in recent years, and their strong social, economic and environmental impact.

Economic evaluation project techniques are an instrument to calculate the costs and benefits related to the decision process in water resources projects, including water desalination plants [13]. Conventional methodologies of project economic analyses, such as the Cost-Benefit Analysis (CBA), are currently applied to compare the economic feasibility associated with the implementation of different project proposals. The CBA starts from the premise that a project should only be accepted, economically feasible, if all the benefits exceed any incurred costs. Although the management of small plants is well-known, information on the desalinated water cost is limited; its final cost is highly variable and appears to be quite site-specific as the cost per cubic meter varies from one installation to the next [14]. As a result, small desalination utilities have been used in most cases, and are implemented without considering any economical evaluation.

This research assesses by CBA and sensitivity analyses the economic performance of three small reverse osmosis (RO) desalination plants, with different characteristics, that operate distinct wells by exploiting the brackish aquifers located in Campo de Cartagena. The primary objective is to assess the water cost for the agricultural irrigation of citrus crops and associated benefits.

2. Study area

2.1. The Campo de Cartagena

The Campo de Cartagena basin, located in southeast Mediterranean Spain (Fig. 1), is a 1440-km^2 plain with elevations ranging between

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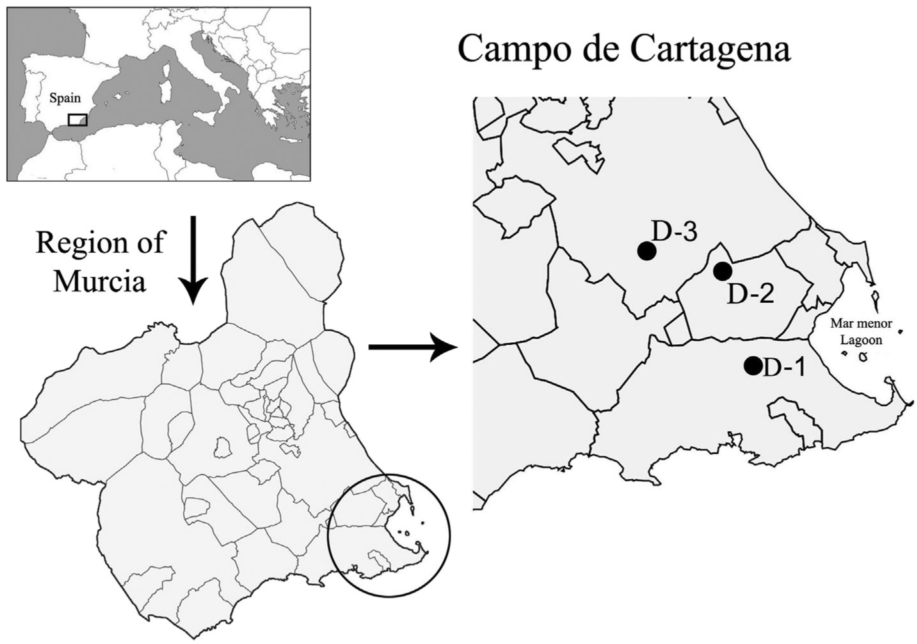

Fig. 1. The Campo de Cartagena study area location. The D-1 to D-3 small desalination plants under study.

sea level and 1065 m.a.s.l. From the hydrological point of view, it is composed of 35 subcatchments, with sizes ranging from 0.2 km^2 to 696 km^2. No permanent watercourse exists and the hydrographic network consists of a number of ephemeral streams that drain to the Mar Menor hypersaline lagoon. To the South and East, the area is limited by the Mediterranean Sea, and by low mountain ranges to the north and west. The region is characterized by a semiarid Mediterranean climate, with an average temperature of 18 °C and 300 mm of annual rainfall distributed unevenly into a few intense events, which are highly variable in space and time [11]. From the geologic standpoint, the Neogene and Quaternary sediments of the Betic Cordillera laid unconformable over highly fractured metamorphic rocks of mainly the Triassic age.

The population's water supply relies mainly on groundwater resources and the Tajo-Segura water transfer, which began in 1980 and transfers water from the Tajo basin (central Spain) to the study area. >2000 boreholes/wells for groundwater exploitation, principally for agricultural purposes, are found in the area. Water resources from desalination plants have markedly increased since 2005 [15]. In recent years, water scarcity has increased due to growing demand and seasonal droughts, and even supply constraints, which occurred in August 2003 and led to 12-hour restrictions being applied to 21 municipalities, with >200.000 inhabitants in the area [16].

Agriculture is the primary land use with 17,968 ha in 2014 (Fig. 2). Drip irrigation is widely used in the region due to scarce water resources and the need for water conservation [17]. Land use distribution in Campo de Cartagena is heterogeneous, with woody crops (lemon, orange, mandarin, olive, vineyards) and herbaceous crops (mainly vegetables) that cover >15.977 ha.

In order to overcome water shortages in the agricultural sector, farmers have chosen to finance and install small private plants (water comes from brackish aquifers, which is unsuitable for direct irrigation) to thus ensure water availability for their crops. Although an inventory

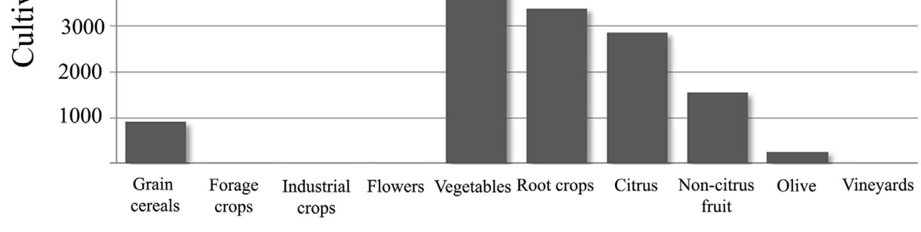

Fig. 2. Hectares of cultivated land and type of crops 2014.
http://www.carm.es/econet/sicrem/PU_CartagenaCifrasNEW/P8004/sec4.html.