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Cost-Benefit Analysis of the Managed Aquifer Recharge System for Irrigation under Climate Change Conditions in Southern Spain

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Abstract: Droughts and climate change in regions with profitable irrigated agriculture will impact groundwater resources with associated direct and indirect impacts. In the integrated water resource management (IWRM), managed aquifer recharge (MAR) offers efficient solutions to protect, conserve, and ensure survival of aquifers and associated ecosystems, as the Water Framework Directive requires. The purpose of this paper is to analyse the socio-economic feasibility of the MAR system in the overexploited Boquerón aquifer in Hellín (Albacete, Spain) under climate change and varying irrigation demand conditions. To assess, in monetary terms, the profitability of the MAR system, a cost-benefit analysis (CBA) has been carried out. The results for the period 2020–2050 showed that the most favourable situations would be scenarios involving artificial recharge, in which future irrigation demand remains at the present level or falls below 10% of the current irrigation surface, as these scenarios generated an internal rate of return of between 53% and 57%. Additionally, the regeneration of the habitat will take between 5 and 9 years. Thus, the IWRM with artificial recharge will guarantee the sustainability of irrigation of the agricultural lands of Hellín and will achieve water balance even in severe climate change conditions.

Keywords: aquifer overexploitation; managed aquifer recharge; climate change; decision support system; cost-benefit analysis; irrigation

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1. Introduction

There is growing concern about the depletion of groundwater levels, lack of water quality, the effects of climate change and the need to meet future water requirements, especially in drought-prone semi-arid regions. This is the case for Southern Spain where the scarcity generates problems in water allocation, mainly for irrigation, and endangers the environmental services that ensure social welfare [1]. Moreover, institutional and governance requirements in the integrated management of water resources (IWRM) aggravate this situation [2]. The Water Framework Directive (WFD; Directive 2000/60/EC) and the Groundwater Directive (Directive 2006/118/EC) advocate achieving "good ecological status" for water resources, achieving a balance between abstraction and recharge that will ensure the survival of aquatic ecosystems and setting deadlines in their planning cycles until 2027 [3]. To face these problems, different practices of conjoint use of surface water and

groundwater are used in Spain, including an artificial recharge system [4]. Dillon [5], defines the Management of Aquifer Recharge (MAR) system as the "intentional banking and treatment of water in aquifers". MAR systems are used to relieve the effects of drought and climate change and provide water to meet demands. Several studies have been carried out with MAR systems, which indicate that these systems are a feasible solution to combat drought and overexploitation of aquifers [5–10]; other studies carried out by Arshad et al. [11] and Maliva [12] have assessed the financial feasibility of MAR and have taken into account the total benefits of MAR. In fact, Maliva [12] showed that MAR systems can be evaluated by direct and indirect measures of willingness to pay. To assess, in monetary terms, the feasibility of MAR, cost-benefit analysis (CBA) is performed, as this is the most common economic tool used by decision makers to accept or reject projects, policies or investment initiatives. CBA has the capacity to improve economic efficiency in projects involving the distribution of water resources and the need to account for environmental effects [13]. According to Maliva [12], MAR systems can provide a series of benefits to water resource management, such as increased volume of stored water, preservation or improvement of water quality, and the relatively low cost for the storage [9]. In addition, MAR Schemes tend to be economically feasible (i.e., they have a positive net present value) when the water is applied for high-value use and when no other more cost-effective alternatives are available, provided that there are favourable hydrogeological conditions. If the value of non-use is also taken into account in the assessment of the environmental benefit of the project, policy or investment, the profitability is increased. According to Bouwer [14], the WFD establishes the economic principles and tools to meet human needs and ensure social welfare. One of the benefits obtained from recovering or improving the use and conservation of water resources involves the non-use value (e.g., support of ecosystems, scenic beauty, and bequest value). This non-use value is usually calculated by stated preference methods such as the contingent valuation method [15,16].

This work complements previous studies carried out on the Boquerón aquifer (Albacete, SE Spain) and the advisability of performing artificial recharge of an overexploited aquifer by Senent et al. [17] and Pérez-Sánchez and Senent-Aparicio [18]. These authors analysed the possibilities of linking surface water with the groundwater of the aquifer due to its proximity to the Hellín canal, which supplies the irrigated area of the municipality with 40% of the total water of the canal. The study concluded that the Boquerón aquifer could be used as a regulating reservoir for the water system of the municipality. In this respect, artificial recharge derived from the surplus water carried along the Hellín canal during the rainy months would be sufficient. For this, two scenarios have been proposed in the course of 20 years of study. A first scenario represented the current situation of direct natural recharge by precipitation, and a second scenario involved artificial recharge (i.e., MAR using wells, including aquifer storage and recovery (ASR). The results carried out by Pérez-Sánchez and Senent-Aparicio [18] found fast depletion of the piezometric levels in the natural recharge scenario, which would lead to the abandonment of the aquifer in 10–15 years, as use of the aquifer would not be economically feasible due to the costs of pumping and the price of energy. However, in the artificial recharge scenario, lower levels would be maintained, guaranteeing the supply of water for irrigation and environmental sustainability. In fact, some springs linked to the aquifer, such as Fuente de Isso (currently dry), would reappear in 5–10 years.

The aim of this study is to use CBA to evaluate the socio-economic profitability of the environmental recovery of the Boquerón aquifer through artificial recharge, taking into account the possible future effects of climate change. This analysis will also consider the influence of the main variables affected (i.e., population and irrigation water consumption) over the profitability indicators, net present value (*NPV*) and internal rate of return (IRR), under different future scenarios of agricultural demand. The importance of this work lies in knowing whether the IWRM, through the MAR system, will guarantee the survival of the agricultural sector of the municipality of Hellín, the recovery of habitat and social welfare in the future. The novelty in this study is the incorporation of the effects of climate change on IWRM in the CBA.

This work will be divided into several sections. The next section will explain briefly the study area. The third section will be divided into two parts: the first part will describe the methodology for modelling the joint management of the aquifer using the decision support system AQUATOOL and the proposal scenarios; cost benefit analysis and costs and benefits included in the CBA will be described in the second part. In the fourth section, the results of both scenarios will be shown. Finally, the results and conclusion will be discussed.

2. Study Area

The municipality of Hellín is located in Castilla La Mancha in Southern Spain and covers an area of about 781.2 km^2 (Figure 1). Its population is 31,262 inhabitants. The average temperature varies between 9.1 °C and 26.3 °C. This region lies in a semiarid environment with scarce rainfall (400 mm yearly average). A more accurate description can be seen in Rupérez-Moreno et al. [19]. These factors are crucial to agricultural development in the region, which has grown due to the recent economic crisis in Spain. In fact, more than 20% of the workforce is currently employed in the agricultural sector [18]. This has led to an increase in the water demand in this municipality.
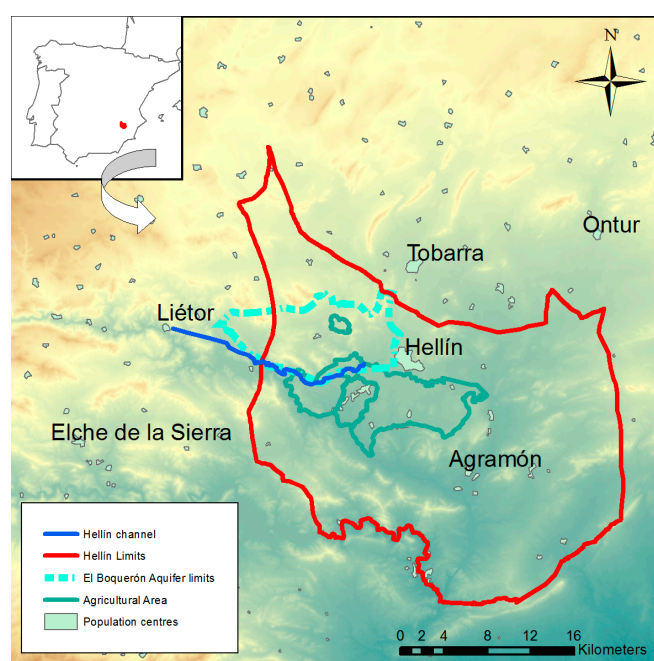

Figure 1. Location of Boquerón aquifer in the Hellín municipality and agricultural area.

Regarding the resources in the Hellín municipality for meeting agricultural demand, 48.74% come from surface resources from the River Mundo, which crosses the municipality in the west, especially the Hellín canal, which accounts for 38.04% of the entire municipality's water supply. The remaining 51.26% comes from different aquifers under the surface of the Hellín municipal district, since 96% of the Hellín municipality sits over aquifers of great capacity and with possibilities for exploitation. However, due to the seasonal nature of demand throughout the years, the surpluses in the Hellín canal between the wettest months from October to April (3.67 hm^3/year average) are not used or stored by the municipal water system, and it loses the power to regulate the resources awarded by the river basin authority to which it belongs. Similarly, in summer (June–September), there is a high deficit in the irrigation activities (8.66 hm^3/year average) associated with the canal, and they are compensated by water from different aquifers, especially the overexploited Boquerón aquifer [18]. From a hydrogeological point of view, the Boquerón aquifer is an important water storage method because it consists of dolomitic fractured bedrock coming from the Chorro age with an average

thickness of 300 m, porosity between 3% and 8% and permeability around 1.15 m/h according to IGME [20]. The aquifer is only confined in its eastern borders, coinciding with the location of the Hellín canal. The artificial recharge of the Boquerón aquifer throughout the surplus water carried along the Hellín canal during the wettest months would increase the water availability in the area by using this aquifer as a "regulating reservoir" of the water resources system of the area.

3. Materials and Methods

3.1. Decision Support System

The water management scenarios have been analysed using the AQUATOOL model [21]. AQUATOOL is a very useful decision support model that is used by Spain's river basin authorities and in many research studies in regions throughout Spain [22,23]. It is capable of simulating the joint management of water resources, as it enables the incorporation of aquifers into the surface water subsystem as another regulation 'deposit'. Two different management water scenarios have been designed: (scenario 1) current management with no interrelation between surface and underground water (business as usual); and (scenario 2) joint management that includes the aquifer of Boquerón as a 'large underground regulation deposit' through recharges using the Hellín canal surplus, as produced in the system [18]. This will make it possible to compare each of the proposed scenarios.

For this study, 30 years of data from historical simulation runs (1971–2000) were used as the baseline period. Meteorological data for this period were obtained from the gridded data set called SPAIN02 [24]. In order to simulate future scenarios, the combination of the Global Climate Model (GCM) EC-EARTH and the Regional Climate Model (RCM) HIRHAM5 was downloaded from the EURO-CORDEX initiative [25] and was used to evaluate climate change in the study area for the period 2021–2050 under two different representative concentration pathway (RCP) emission scenarios (RCP4.5 and RCP8.5). This GCM-RCM combination has been recently and satisfactorily applied near the study area [26]. A bias correction technique based on distribution mapping of precipitation and temperature was applied to the downscaled data in order to increase the accuracy of the results.

On the other hand, the water inputs have been introduced as historic monthly values for both climate change scenarios. The demands are introduced as average monthly values. Once the elements of the system and the relationships between them have been configured [18], the model is defined as an optimization problem that can be expressed across a target function and a set of limitations [27] and is solved using the Out-of-Kilter algorithm [28]. Aquifer recharge was obtained with Visual Balan [29] for both emission scenarios.

Water Management Scenarios under Climate Change Conditions

This work complements the studies carried out by Senent et al. [17], Pérez-Sánchez and Senent-Aparicio [18], and Rupérez-Moreno et al. [19] in the Boquerón aquifer. The scenarios found in these studies have been updated and include the effects of climate change.

The project has considered the 30-year study (2021–2050) under two comparative emission scenarios (RCP4.5 and RCP8.5) that could reflect the consequences of incorporating the aquifer of Boquerón into the water system, as described: scenario 1 (SC1) is the current water management (business as usual) system with no joint management of surface water and groundwater; and scenario 2 (SC2) is the joint water management system.

The system to be simulated in SC1 takes into account the current behavior pattern. In this scenario there is no conjoint use of the surface and underground water. The surplus water supplied by the Hellín canal is returned to the surface sub-system when it is not consumed. In the second scenario (SC2), the consideration of supply and demand is the same as in scenario 1, except that the aquifer of El Boquerón—besides receiving its natural source of supply from rainfall over the permeable outcrops of this formation—will be artificially recharged by the monthly surplus from the surface water resources of the Hellín canal (mainly from November to March).

According to Iglesias [30], the effects of climate change in terms of (increased) demands in the basin will reach approximately 7%. However, due to the uncertain economic future, other authors prefer to consider a sensitivity analysis of plus and minus 10% irrigation demand, as this represents a pessimistic scenario dominated by physical changes, and an optimistic scenario driven by policy adjustments [31]. A code is used to summarise each of the water schemes evaluated according to the two scenarios. These are devised as follows: Scenario 1 or 2 plus the emission scenario plus the variation in demands. For instance, scenario SC1-RCP4.5-0 represents the current management with emission scenario RCP4.5 and no variation in demand. Scenario SC2-RCP8.5+10 represents conjoint use of water resources according to emission scenario RCP8.5 and a demand that is +10% greater than at present.

3.2. The Analytical Framework for Cost-Benefit Analysis

The cost-benefit analysis (CBA) is a decision-making tool for obtaining the economic and/or social profitability of a public investment, policy or initiative by means of a comparison among costs and benefits resulting from proposed measures [32–34]. In addition to considering the net private cash flows (revenues minus expenses), the CBA takes into account the social costs and benefits. According to Almansa and Martínez-Paz [35] the CBA can incorporate the criteria of social profitability and intergenerational sustainability, which are valued according to social welfare. Furthermore, the actions undertaken in the planning and integrated management of water resources have a significant impact on the environment [2]. According to Carson [15] and Birol et al. [16] the environmental goods and services have a non-market value. Hence, they should be included in cost-benefit analyses. In this study, a contingent valuation method has been used to obtain the non-market values, because it is the most common economic tool used to assess non-use values [16,19].

CBA was devised before the French Revolution and was developed in the works of Dupuit [36, 37]. Even though CBA originated in economic feasibility studies of public water projects such as irrigation, water supply and flood control, the scope of its applications has grown [33]. In the field of water resources, Bouwer [38] gives an overview of CBA throughout Europe and North America. Regarding the MAR system, previous studies have illustrated the use of CBA to evaluate the feasibility of this type of system [9,11]. However, few have included non-use value in the attainment of socio-environmental benefits, such as in Todd [39] and Maliva [12].

The phases in the design of a cost-benefits analysis are as follows [40]:

1. Identify and assess, in monetary terms, all costs and benefits of the action;
2. Establish the horizon year of the assessment;
3. Fix the discount rate;
4. Make selection profitability indicators;
5. Analyse the most uncertain variables.

3.2.1. Cost Analysis

The calculation of the costs involved in the exploitation of the Boquerón aquifer has been carried out using the methodology of the work done by Rupérez-Moreno et al. [41], which collected the costs of extraction, distribution and farming of the main overexploited aquifers in the Segura basin, to which the aquifer belongs. Specific wells in each overexploited aquifers, trends in evolution of water table and features of each irrigation zone associated with these aquifers were considered. Moreover, technical and financial parameters were collected to evaluate groundwater exploitation costs, such as economic inquiry regarding the investment and operating costs of installations for pumping and irrigation (e.g., piping and drilling, construction and installation work of pumping equipment, irrigation pond construction, and irrigation system installation), analysis of the hydrogeological characteristics of the different overexploited aquifers, and economic valuation of each associated representative well and irrigation area. In this work, the cost per cubic meter of extracted water was estimated, accepting

some hypotheses: adopting current minimum values of costs; not considering certain costs that should only be considered on an exceptional basis (e.g., electric power line, chlorination); not including the cost of project and construction management; not considering VAT; not including land purchase, because it is assumed already available; taking into account only those components of the irrigation cost in direct relation to the water used. However, in this study an overall economic evaluation with stakeholder participation has been carried out. Moreover, the environmental and resource costs have been considered regarding the total economic value of the environmental damage as a result of the Boquerón aquifer overexploitation. They have been estimated in monetary terms by stated preference techniques for environmental valuation by the contingent valuation method as shown in [19].

The total cost was divided into a series of partial costs identified with the main work units that constitute the catchment and transportation of groundwater to its point of use (i.e., extraction and distribution). Each unit represented an investment and the annual expenses, constant or variable (i.e., energy, conservation, replacement, employees), during its lifespan. The generating units of investment considered were: well construction, booster pump installation, water booster installation, irrigation ponds and localised irrigation systems.

A standard interest rate of 5% and the amortization periods associated with the life of the different units (i.e., 20 years for the well, reservoirs and irrigation; 10 years for the electromechanical installation of pumping and transport installation) were considered to obtain the amortization annuities. The operating costs included the maintenance costs, which included repairs and personnel costs; the monitoring and operating costs of the installation; and the energy costs, which depended on the pumped flow rate and the kWh price.

The exploitation cost was calculated as follows:

$$CE = 0.004 \times V \times h_m \times e + c_m \tag{1}$$

where 'V' stands the annual volume of extracted water (m^3); 'h_m' is the pump head (m); 'e' is the energy price (€/kWh), which will vary from time to time; and 'c_m' is the maintenance cost (€), which is 3% of the total investment.

Regarding artificial recharge, the DINA-MAR (Depth Investigation of New Areas for Managed Aquifer Recharge) project was carried out with the goal of determining the most suitable areas for MAR activity "MAR Zones" in Spain. This project has cartography available at the DINA-MAR "Visor cartográfico" website [42] that synthesizes the physical characteristics that lead to its determination. The web application called "HidroGeoportal DINA-MAR" manages an important volume of information that helps in water decision-making policies or investments. This project also has a map of "iso-costs" to estimate the average investment and maintenance cost in a MAR Zone, depending on the origin of the water sources, either of fluvial in origin or sewage waters [9]. Since the Boquerón aquifer is located in an MAR Zone and the recharge comes from the Hellín canal, the map of iso-costs was used to estimate the investment cost and the maintenance cost: €0.2/m^3 and €0.01/m^3, respectively. The artificial recharge considered would be carried out by building infiltration wells whose positive results were shown by the previous experiences gained in this area [17]. These test wells are still used by the irrigation communities, albeit sporadically and void of planning [18]. No water treatment will be necessary due to the average nitrate concentration (30 mg/L) and sulphate concentration (750 mg/L) in the Hellín canal water used [43].

All these costs were calculated in twelve scenarios, six for the current management scenario (SC1) and six for the artificial recharge scenario (SC2), depending on the emission scenarios (RCP4.5, RCP8.5) and the agricultural demands (i.e., 0, −10%, +10%).

As can be seen in Table 1, the investment costs in SC1 will only appear when the future irrigation demand increases by 10%. In the 0% and −10% sub-scenarios, all infrastructures are assumed to be made and amortized, as the Boquerón aquifer has been exploited for many years for irrigation [17–19]. In the joint management proposal (SC2), the cost of investment for the 0% and −10% sub-scenarios would be equivalent to artificial recharge, and for the +10% scenario, investment in the construction of

new wells, pumping facilities, reservoirs and irrigation systems, etc., which would be needed to meet this demand, would be added.

Table 1. Investment costs of the Boquerón aquifer under emission scenarios RCP4.5 and RCP8.5.

Emission Scenarios RCP4.5 and RCP8.5			
Irrigation demand	0	−10%	+10%
SC1 Investment (€)	0	0	13,592,559
SC2 Investment (€)	1,195,320	1,331,085	14,668,011

3.2.2. Benefit Analysis

The benefits generated by the exploitation of the El Boquerón aquifer were divided into two categories: the private benefits evaluated as market revenues minus costs, and the socio-environmental benefits generated by the preservation of the ecological status of the aquifer and the groundwater-dependent ecosystems.

The benefits created by the market revenues relate to the economic value of agricultural production in Castilla La Mancha, as irrigation represents the main user of groundwater in the region [18]. Furthermore, the socio-environmental benefits were associated with the population of the municipality of Hellín because this is a determining factor in the economic valuation of an environmental asset [44]. The market revenues generated by the exploitation and use of the groundwater of the El Boquerón aquifer correspond to the 10% final agricultural crop production of Castilla La Mancha [41]. According to Córcoles et al. [45], the value of agricultural production in Castilla La Mancha was 1.67 €/m^3. Considering this value for the reference year 2021, production in the 30-year studied period was obtained by multiplying this value by the annual consumption of water used for irrigation.

The socio-environmental benefit was carried out through a contingent valuation exercise in which a representative sample of the population of Hellín was interviewed and asked about the maximum willingness to pay (WTP) for the environmental improvement of the Boquerón aquifer and the sustainability of agriculture in the municipality [19]. In this work, carried out by Rupérez-Moreno et al. [19], the stakeholders participated in the economic valuation of the proposed measures through surveys (public consultation). The target population was defined by considering the number of households of Hellín municipality with an average of 3.15 people per household [46]. The study sample comprises 9924 households with a total of 240 surveys conducted by simple random sampling. The elements of the simulation of a hypothetical market of the contingent valuation exercise were the WTP and the form of payment: an increase in the water bill over one year. Respondents were asked if they would or would not pay to improve the ecological status of the water bodies of the Boquerón aquifer (dichotomous binary format). If the answer was yes, the respondent should declare their maximum WTP for the implementation of the proposed measures so the benefits derived could be quantified. The implied variables in the contingent valuation were income, employment and green commitment. The mean WTP of the hypothetical market was €18.89 (±28.627) per year with a median value of €12 per year. The mean WTP multiplied by the target population provides a benefit of €187,464 per year. Moreover, because the CVM estimates both the use and non-use values of the environmental assets, the total economic value (TEV) can be decomposed into the sample of individuals who are users of the area above the aquifer and those who are not. The use value (direct and indirect) of conjoint water resources management in the municipality of Hellín would mainly comprise drinking water and industrial consumption, agricultural irrigation, recharge to the aquifer of Boquerón and recreational use of the Fuente de Isso wetland and the other wetlands and springs in the area. Meanwhile, the non-use value would correspond to the support of the ecosystem associated with the aquifer, the scenic beauty of the area, and the bequest value, whereby future generations could enjoy this environmental resource. The socio-environmental benefit was directly identified by reference to the WTP of non-users, which resulted in €14.86 per year for a sample of 172 households. To aggregate this value for the whole of the Hellín population, the WTP of non-users

was calculated by multiplying the mean WTP non-users by the total household. Finally, the future projection of the households included in the CBA during the analysis period 2021–2050 was estimated using an autoregressive model following the procedure in Hildreth and Lu [47], which is based on the historical series of this variable [46]. It is assumed that the socio-environmental benefit is the same in each scenario because it is difficult to know how the perception of the environmental issues will develop in the future population.

3.2.3. Profitability Indicators

The most commonly used profitability indicators in water resources management are the net present value (*NPV*) and the internal rate of return (IRR). The *NPV* considers both the initial investment in the project and the costs and benefits generated during the life of the project. Taking into account the non-use values in the CBA, a differentiated *NPV* has been used in this study. Hence, future private benefits have been discounted at a market rate, and the socio-environmental benefits at an ecological rate. The discount rate is the present value of a future payment. From the point of view of a society, it reflects whether a present benefit is more valuable than the same benefit obtained in the future [48]. The ecological discount rate provides the criteria of sustainability and intergenerational equity required in projects with long-run environmental consequences on future generations. That is a challenge for water decision-makers who should determine the desirability of this type of project, taking into account the importance of intergenerational sustainability [49,50].

The *NPV* applied in this study is as follows:

$$NPV = -k + \sum_{t=1}^{t} \frac{NCF_p}{(1+r)^t} + \sum_{t=1}^{t} \frac{NCF_e}{(1+r_e)^t} \tag{2}$$

where 'K' stands initial investment cost, 'NCF_p' is the private net cash flow, 'r' is the market discount rate, 't' is the time, 'NCF_e' is the socio-environmental net cash flow, and 'r_e' is the ecological discount rate.

In accordance with European Commission recommendations [51], a 5.5% market discount rate has been considered for this type of investment. Regarding the environmental discount rate, Almansa and Martínez-Paz [50] suggests a lower environmental rate of 3.5% for projects or investments from 0 to 30 years. When considering different discount rates, the loss of value in the future will be different in each case.

Finally, the IRR is the discount rate that converts the *NPV* to zero, that is, the value for which investment costs are equal to benefits. The value is a percentage that indicates the profitability associated with the net cash flows. The higher the IRR, the greater the profitability of the project and the more desirable it will be to undertake it. When there are different discount rates, the IRR value is obtained by keeping the environmental rate constant.

4. Results

4.1. Results from AQUATOOL

Evolution in the natural recharge of the Boquerón aquifer depends on the emission scenario, as can be seen in Figure 2a–c. Despite the high peaks of natural recharge in the RCP8.5 emission scenario, the cumulative recharge in the studied period was 20% lower than in the RCP4.5 emission scenario, with an average recharge of 0.98 hm^3/year in RCP4.5 compared to an average of 0.80 hm^3/year in RCP8.5. However, the artificial recharge in the joint management (SC2) system was higher than in the natural one, regardless of the demand hypothesis, which is, on average, 5.7, 6.3 and 5.12 hm^3/year for non-variation in demand, representing an increase of 10% and a decrease of 10%, respectively.
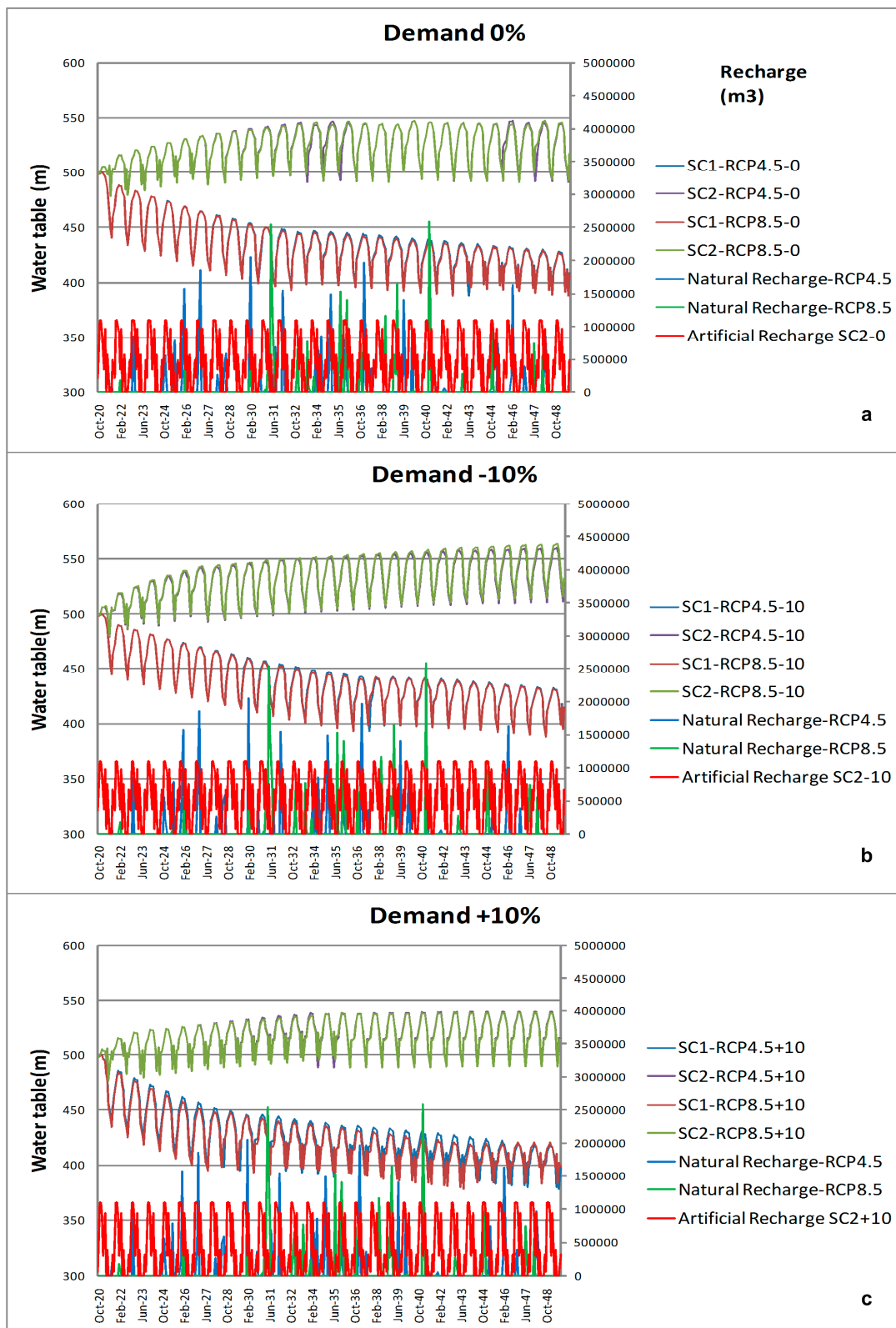
Figure 2. Evolution in water table and aquifer recharge: (**a**) without variation in irrigation demand; (**b**) with a fall in irrigation demand of 10%; (**c**) with an increase in irritation demand of 10%.

Concerning the demand deficits for crop irrigation, both scenarios ('business as usual' and joint management) showed that a 10% reduction in the size of the croplands would also reduce the deficit

in the demands by, on average, 30% for all croplands depending on a groundwater supply in both emission scenarios. Furthermore, the joint management reduction in demand and, consequently, the rising water tables in Boquerón would lead to the absence of a deficit in the last 20 years of the studied period in the RCP4.5 emission scenario and in the last 18 years in the RCP8.5 emission scenario. Even with an increase of 10% in demand, there would be no deficit in the last 15 years of the studied period provided that the surpluses from the Hellín canal were used to recharge the Boquerón aquifer. However, with regards to the croplands, which strongly depend on surface water resources, there would be only a 2% reduction in the deficit compared to the current management scenario.

Regarding the trend in the water table in the Southern part of the area (Figure 2), where most of the pumped abstractions are made, it can be seen that there are big differences between the current water management system and the joint management system for all demand and emission scenarios. SC1 (business as usual) showed rapid decreases in water tables, falling from a current level of 498 m above sea level to 398 MAMSL on average in both scenarios SC1-RCP4.5+10 and SC1-RCP8.5+10 (Figure 2c), and to 414 MAMSL in scenarios SC1-RCP4.5-10 and SC1-RCP8.5-10 (Figure 2b), with a slightly higher decrease (less than 1 m) in emission scenario RCP8.5 than in emission scenario RCP4.5. If there was no variation in demand (Figure 2a), the water tables would vary between the above values.

The joint management (SC2) system, whereby the Boquerón aquifer is incorporated into the system as a regulation reservoir, showed an increase in the water table for all the demand hypotheses, although the rate of increase and the water levels at the end of the studied period were hugely influenced by them (Figure 2). If the irrigation demand remains constant or decreases, the water table would increase at around 1 m/year, and an increase of 10% in crop irrigation demand would occur, rising by 0.50 m/year. The recovery of the levels would also enable the reappearance of springs (now dry) and the regeneration of the associated ecosystems within 6–9 years in SC2-RCP4.5 or RCP8.5-0, 11–15 years in SC2-RCP4.5 or RCP8.5+10, and 5–7 years in SC2-RCP4.5 or RCP8.5-10.

4.2. Results from CBA Analysis

The profitability indicators, *NPV* and IRR, in the current management scenarios (SC1), joint management (SC2) and their respective sub-scenarios, taking into account emission scenarios RCP4.5 and RCP8.5 and future irrigation demands of 0%, −10% and +10%, are shown in Tables 2–5.

Table 2. Net present value for the Boquerón aquifer in emission scenario RCP4.5 with irrigation demands.

NPV **Emission Scenarios RCP4.5**				
Irrigation demand		**0%**	**−10%**	**+10%**
SC1	NPV (€)	22,422,403	21,457,499	−1,935,893
SC2	NPV (€)	30,456,618	29,687,600	17,284,521

Table 3. Net present value for the Boquerón aquifer in emission scenario RCP8.5 with irrigation demands.

NPV **Emission Scenarios RCP8.5**				
Irrigation demand		**0%**	**−10%**	**+10%**
SC1	*NPV* (€)	21,808,825	21,453,414	8,217,789
SC2	*NPV* (€)	30,446,086	29,890,890	17,209,651

Table 4. Internal rate of return for the Boquerón aquifer in emission scenario RCP4.5 and irrigation demands.

IRR Emission Scenarios RCP4.5				
Irrigation demand		**0%**	**−10%**	**+10%**
SC1	IRR (%)	-	-	3.39%
SC2	IRR (%)	57.54%	53.16%	11.76%

Table 5. Internal rate of return for the Boquerón aquifer in emission scenario RCP8.5 and irrigation demands.

	IRR Emission Scenarios RCP8.5			
Irrigation demand		**0%**	**−10%**	**+10%**
SC1	IRR (%)	-	-	11.76%
SC2	IRR (%)	57.56%	53.33%	11.73%

The results show that the SC2 would be more profitable than the current management scenario SC1, regardless of the emission scenario and the irrigation demand hypothesis. Relating to SC1, profitability would be obtained by increasing the crops area in the emission scenario RCP8.5 (i.e., the IRR would be 11.76% above the market rate of 5.5%). However, there is no environmental benefit in this scenario. In SC2-RCP8.5+10, when considering the environmental benefit, a similar value was obtained (IRR = 11.73%), but this is due to the fact that the initial investment corresponding to the artificial recharge is much lower than the investment in the construction of new infrastructure that would be necessary to exploit the aquifer and distribute the water at the plot. Even so, the values are well below the irrigation demand scenarios 0 and −10%. Moreover, in SC2 the highest profitability would be obtained for future agricultural demands of 0 and −10%. In fact, the highest *NPV* values corresponded to the scenarios SC2-RCP4.5-0 and SC2-RCP8.5-0 with very similar values of €30,456,618 and €30,446,086, respectively. These scenarios also had an IRR of 57.54% and 57.56%, respectively. These values are very high compared to the market discount rate due to the fact that the internal rate of return increases considerably when the environmental benefits are taken into account.

5. Discussion

In this study, the most uncertain variables were the population in the socio-environmental benefit and the irrigation water consumption in the private benefit. The population variable does not influence the different scenarios. The socio-environmental benefit calculation should take into account the fact that a greater perception of the environmental issues would arise in those unfavourable scenarios. Therefore, the contingent valuation could be increased annually, but it is difficult to determine whether it will produce this variation. Hence, in this case the socio-environmental benefit has been considered as constant for all the scenarios. In contrast, the water consumption variable for irrigation will have an influence in each of the different scenarios because it depends on the future irrigation demand and the current demand, which is represented in the scenarios 0%, −10% and +10%. Thus, a sensitivity analysis was not performed, as these same scenarios reflect the variability of the changes when considering the evolution of the population in 30 years and the increase or decrease of the irrigation demand.

Considering the effects of climate change and independently of the hypotheses of agricultural demand, the artificial recharge in the joint management system would be greater than the natural recharge in the current management system in the next 30 years of study. Reducing crop size by 10% would reduce the water demand deficit by approximately 30% and would increase the water table of Boquerón by approximately 1 m/year. In contrast, agricultural production would also be reduced and would influence private net profit and social profit (lower production implies less employment). However, if the crop area increased by 10%, the water table would only increase by 0.50 m/year. Even if this situation entails a larger initial investment, the benefits from the sale of crops would also increase, but the profitability would be much lower than in the irrigation demands of 0% and −10%.

On the other hand, in scenario SC1, the profitability offered by the current management system would increase the agricultural production area by 10%, as the results show an IRR 11.76% greater than the 5.5% market discount rates. But in this scenario, the benefits obtained would be only private because any investment that supposes an environmental benefit is carried out. According to Almansa and Martínez-Paz [35], the most favourable profitability from an economic and social point of view would be one that takes into account the environmental benefits, as the WDF establishes. Perhaps

the decline in the irrigation area, along with recent public and private investments in irrigation modernization to improve water efficiency, will help mitigate the effects of drought and climate change and ensure environmental sustainability [52]. In order not to affect the benefits of agricultural crop production, the scenario of an artificial recharge with future demand equal to the current one could be the most feasible solution in any of the emission scenarios that occur (i.e., SC2-RCP4.5-0 or SC2-RCP8.5-0), because the values of *NPV* and IRR are very similar. However, there is a trend towards the growth of irrigation, so the SC2-RCP4.5 or RCP8.5+10 scenario are more likely to occur. Nevertheless, the regeneration of ecosystems will take longer than other scenarios in the order of 11–15 years in irrigation demand scenario +10% versus 5–9 years in the 0% and −10% scenarios.

As a future line of research, it would be helpful to calculate the probability that each scenario and sub-scenario will occur. In this way, the IRR could be modified by weighing the probability of the occurrence of such scenarios. Perhaps one of the appropriate methods to perform this weighting could be the Monte Carlo simulation due to its robustness, as it establishes the acceptance or rejection thresholds for an investment project [34].

6. Conclusions

MAR systems are the most economically and socially feasible solution to the integrated management of water resources even under climate change conditions. In those regions prone to serious drought where the aquifers suffer from overexploitation while supplying irrigation demands—as in the case of the Boquerón aquifer—the profitability of the MAR system increases because the environmental benefits of artificial recharge are considered. The results of the cost-benefit analysis carried out in relation to the Boquerón aquifer showed that the most profitable future scenarios will be those that carry out the joint management of the surface water and groundwater of the aquifer, which would operate as a regulating reservoir for the water system. Taking into account future irrigation demands, the most favourable situation would occur in the scenario where future irrigation demand remained at or below 10% of current agricultural demand, because this scenario produces a higher IRR, regardless of the more or less optimistic climate change outcome. In addition, the recovery of the levels in SC2 will enable the reappearance of springs that are currently dry, and the regeneration of the associated ecosystems in 5–9 years approximately in both scenarios of SC2-RCP4.5 or RCP8.5-0 and SC2-RCP4.5 or RCP8.5-10.

Therefore, the conjoint use of surface water and groundwater ensures the quantitative and qualitative improvement of the aquifer, environmental sustainability in the future as well as offering a safer supply guarantee. It is true that uncertainty about the availability of groundwater, depletion and legal limitations produce lack of confidence in investment projects and affect socio-economic and environmental development in regions with scarcity issues. CBA demonstrates that artificial recharge will allow the profitable continuation of irrigated agriculture.

Finally, taking into account the growth of agricultural demand in many countries that intensively exploit aquifers and the consequent ecological damage, the presented methodology would serve as an application guide to ensure that the water supply is treated in a safe way in these countries.

Author Contributions: Javier Senent-Aparicio and Julio Pérez-Sánchez designed the study; Javier Senent-Aparicio, Julio Pérez-Sánchez, Carmen Paz-Aparicio and Carmen Rupérez-Moreno analysed the data from AQUATOOL; Pilar Flores-Asenjo, Carmen Paz-Aparicio and Carmen Rupérez-Moreno analysed the data from CBA; Finally, Carmen Rupérez-Moreno and Julio Pérez-Sánchez wrote the manuscript.

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