

ADAPTING IRRIGATED AGRICULTURE TO REDUCED WATER TRANSFERS: THE ROLE OF NON-CONVENTIONAL WATER RESOURCES IN SOUTHEASTERN SPAIN

ADAPTER L'AGRICULTURE IRRIGUÉE À LA DIMINUTION DES TRANSFERTS D'EAU : LE RÔLE DES RESSOURCES EN EAU NON CONVENTIONNELLES DANS LE SUD-EST DE L'ESPAGNE

C. Villacorta Ranera ^{1,2}, I. Blanco Gutiérrez ^{1,2}, A. Escrivá-Bou ³, and P. Esteve ^{1,2}

ABSTRACT

Water scarcity is a growing challenge in Mediterranean regions, where climate change and increasing water demand are intensifying pressure on limited resources. In southeastern Spain, the Tagus–Segura Transfer (TST) has historically played a key role in supporting irrigated agriculture. However, environmental regulations and climate change are expected to reduce transfer volumes by approximately 40% by 2027, raising concerns about the future viability of agricultural production. In this context, non-conventional water resources (NCW), particularly desalinated and reclaimed water, are increasingly promoted as alternative supply sources.

This study evaluates the impacts of reduced TST allocations on irrigated agriculture and assesses the capacity of NCW to compensate for future water shortages in the Campo de Cartagena Irrigation Community (CRCC), one of the largest and most productive irrigation districts in Spain. To achieve this objective, an agro-economic Positive Mathematical Programming (PMP) model was developed and calibrated using data from the 2018–2020 period. Six scenarios were analysed, including transfer reductions, expansion of NCW supplies, groundwater and desalination constraints, subsidised desalinated water, and full cost recovery pricing.

The results show that a 40% reduction in TST supplies decreases total water use by 23%, reduces cultivated area by 27%, lowers farm profit by 14%, and causes a 22% decline in agricultural employment. Increased use of desalinated and reclaimed water can largely offset water shortages and maintain agricultural activity, although at higher production costs. Desalinated water emerges as the main alternative source, but its economic viability depends heavily on public subsidies. While subsidised desalinated water allows farm profits to approach baseline levels, each additional euro of farm profit generated requires approximately one euro of public expenditure.

The findings highlight that the long-term sustainability of irrigated agriculture in southeastern Spain will require a combination of expanded desalination capacity, renewable energy investments, integrated water resource management, and policies that balance economic, environmental, and social objectives.

Keywords: Mediterranean regions; water shortages; Public expenditure; renewable energy; water resources.

1 Universidad Politécnica de Madrid, Department of Agricultural Economics, Statistics and Business Management, ETSIAAB, Madrid, Spain

2 Centro de Estudios e Investigación para la Gestión de Riesgos Agrarios y Medioambientales (CEIGRAM), Universidad Politécnica de Madrid, Madrid, Spain

3 University of California, Davis, Department of Civil and Environmental Engineering, Davis, United States

RÉSUMÉ

La pénurie d'eau constitue un défi croissant dans les régions méditerranéennes, où le changement climatique et l'augmentation de la demande en eau accentuent la pression sur des ressources limitées. Dans le sud-est de l'Espagne, le transfert Tage-Segura (TST) a historiquement joué un rôle clé dans le soutien de l'agriculture irriguée. Cependant, la réglementation environnementale et le changement climatique devraient entraîner une réduction des volumes transférés d'environ 40 % d'ici 2027, ce qui soulève des inquiétudes quant à la viabilité future de la production agricole. Dans ce contexte, les ressources en eau non conventionnelles (NCW), en particulier l'eau dessalée et l'eau recyclée, sont de plus en plus mises en avant comme sources d'approvisionnement alternatives.

Cette étude évalue les impacts de la réduction des allocations du TST sur l'agriculture irriguée et examine la capacité des NCW à compenser les futures pénuries d'eau au sein de la Communauté d'irrigation du Campo de Cartagena (CRCC), l'un des districts d'irrigation les plus vastes et les plus productifs d'Espagne. Pour atteindre cet objectif, un modèle agroéconomique de programmation mathématique positive (PMP) a été développé et calibré à partir de données de la période 2018-2020. Six scénarios ont été analysés, portant notamment sur les réductions de transferts, l'augmentation de l'approvisionnement en NCW, les contraintes liées aux eaux souterraines et au dessalement, l'eau dessalée subventionnée et une tarification basée sur le recouvrement intégral des frais.

Les résultats montrent qu'une réduction de 40 % des apports du TST entraîne une baisse de 23 % de la consommation totale d'eau, une diminution de 27 % de la superficie cultivée, une baisse de 14 % des bénéfices agricoles et une baisse de 22 % de l'emploi agricole. Le recours accru à l'eau dessalée et à l'eau réutilisée peut largement compenser les pénuries d'eau et maintenir l'activité agricole, bien qu'à des coûts de production plus élevés. L'eau dessalée apparaît comme la principale source alternative, mais sa viabilité économique dépend fortement des subventions publiques. Si l'eau dessalée subventionnée permet aux bénéfices agricoles de se rapprocher des niveaux de référence, chaque euro supplémentaire de bénéfice agricole généré nécessite environ un euro de dépenses publiques.

Ces résultats soulignent que la pérennité à long terme de l'agriculture irriguée dans le sud-est de l'Espagne nécessitera une combinaison de plusieurs mesures : augmentation des capacités de dessalement, investissements dans les énergies renouvelables, gestion intégrée des ressources en eau et politiques conciliant les objectifs économiques, environnementaux et sociaux.

Mots-clés : Régions méditerranéennes; Pénurie d'eau; Dépenses publiques; Energies renouvelables, Ressources en eau.

INTRODUCTION

Water scarcity is a major global challenge, particularly in arid and semi-arid regions where climate variability and intensive agricultural activity place increasing pressure on limited water resources (Senent-Aparicio et al., 2021). This problem is especially acute in Mediterranean regions (Vinci et al., 2021). Traditionally, many countries have addressed water imbalances through inter-basin water transfers, which divert water from areas with surplus resources to regions facing shortages (Ghadirian Baharanchi et al., 2024). Although these systems have supported economic development and water supply, they have also generated significant socio-environmental concerns and involve high energy requirements, while potentially encouraging unsustainable consumption patterns in receiving regions (Morote et al., 2020).

In response, water management strategies are increasingly incorporating non-conventional water sources (NCW), particularly desalinated and reclaimed water, to enhance water security and reduce dependence on overexploited conventional resources (Ricart et al., 2021). Desalinated water offers a climate-independent supply and is especially valuable during drought periods (Villar-Navascués et al., 2020). However, its adoption is constrained by high production costs, substantial energy requirements,

and environmental impacts associated with brine disposal (Martínez-Medina et al., 2024). Reclaimed water, meanwhile, improves water-use efficiency by reintroducing treated wastewater into the hydrological cycle and may provide additional agronomic benefits through nutrient content (Verlicchi et al., 2023). Nevertheless, concerns regarding salinity, emerging contaminants, and public acceptance continue to limit its wider use (Santos et al., 2023).

Spain, particularly its Mediterranean regions, has become a leading example of NCW implementation. The AGUA Program promoted major investments in desalination infrastructure, while Royal Decree 1620/2007 established a regulatory framework for water reuse. More recently, Royal Decree 1085/2024 aligned Spanish legislation with EU Regulation requirements and further strengthened the promotion of reclaimed water. Desalination has also gained renewed support through infrastructure expansion and increased public investment, consistent with European initiatives such as the EU Water Resilience Strategy, which promotes circular water management and diversified water supply portfolios.

The Segura River Basin (SRB), located in southeastern Spain, represents one of the most water-scarce regions in Europe. Its structural water deficit has historically been addressed through a combination of reservoirs, groundwater abstraction, inter- and intra-basin transfers, and more recently, desalinated and reclaimed water (Gómez-Ramos et al., 2024). A key component of this system is the Tagus–Segura Water Transfer (TST), a 300-km infrastructure operating since 1979 that supplies water for irrigation and urban uses (Morote et al., 2020). Despite its strategic importance, recent environmental regulations and climate change impacts are expected to significantly reduce transfer volumes, with projections indicating reductions of approximately 40% by 2027 and up to 60% by 2039 (CHS, 2022c).

Although previous studies have extensively analysed the TST from governance, economic, environmental, and climate adaptation perspectives (Azorín et al., 2025; Bourguignon et al., 2024; Cañizares et al., 2022; García-López et al., 2022, 2023; Morote et al., 2020), limited attention has been paid to the capacity of NCW to compensate for future transfer reductions. Existing research has largely relied on qualitative approaches, leaving a gap in quantitative assessments of alternative water management scenarios (Gómez-Ramos et al., 2024).

This study addresses this gap by evaluating the impacts of reduced TST inflows on irrigated agriculture and analysing the potential of desalinated and reclaimed water to offset these reductions. To achieve this objective, an agro-economic Positive Mathematical Programming (PMP) model is applied. PMP models are widely used to assess how agricultural systems respond to changes in resource availability, policy interventions, and market conditions (Layani et al., 2023). The analysis focuses on the Campo de Cartagena Irrigation Community (CRCC), the largest and most technologically advanced irrigation district within the SRB (Gómez-Ramos et al., 2024).

Case Study

The CRCC located in southeastern Spain, is one of the largest and most productive irrigation districts in the country. Characterized by a semi-arid Mediterranean climate, the area receives approximately 300 mm of annual rainfall and has an average temperature of 18°C (Gil-Meseguer et al., 2024). Established in 1952, the CRCC comprises nearly 9,700 members and irrigates 42,255 hectares across municipalities in the Region of Murcia and the Valencian Community (García Castellanos et al., 2024; MAPA, 2024b).

Agriculture in the CRCC plays a key economic role. In 2022, agricultural production reached approximately €346 million, representing more than 15% of Murcia's agricultural output and nearly 1% of Spain's total agricultural production (CHS, 2022b; MAPA, 2022a). Vegetables, including lettuce, cauliflower, peppers, melons, and artichokes, occupy 53% of the irrigated area, while citrus crops account for 22%.

The CRCC relies on a highly diversified water supply portfolio. Between 2018 and 2020, the TST provided 48.5 hm³, representing 42.5% of total water resources. However, transfer volumes have shown considerable variability, ranging from 83.5 hm³ in 2014 to only 17 hm³ during the 2016–2017 drought.

Groundwater supplied 33.5% of demand, while desalinated seawater and reclaimed water contributed 13.3% and 5.3%, respectively. Smaller contributions came from surface water, brackish water desalination, and water rights transfers (MAPA, 2024; Soto García, 2020).

The future availability of conventional resources is increasingly uncertain. Local aquifers suffer from overexploitation, nitrate pollution, and seawater intrusion (Alcolea et al., 2019). At the same time, the Segura River Basin Management Plan (SRBMP) proposes a 40% reduction in TST allocations and tighter restrictions on groundwater abstraction by 2027 (CHS, 2022c). These reductions are expected to be partially compensated by NCW, particularly desalinated water. While the expansion potential of reclaimed water is limited because most wastewater treatment plants already operate near capacity, desalination offers greater opportunities for growth. Planned expansions of the Torrevieja desalination plant and other facilities could increase desalinated water availability to approximately 45.2 hm³ by 2027 (CHS, 2022c).



Figure 1. Location of the Irrigation Community of Campo de Cartagena (CRCC). Source: Own elaboration.

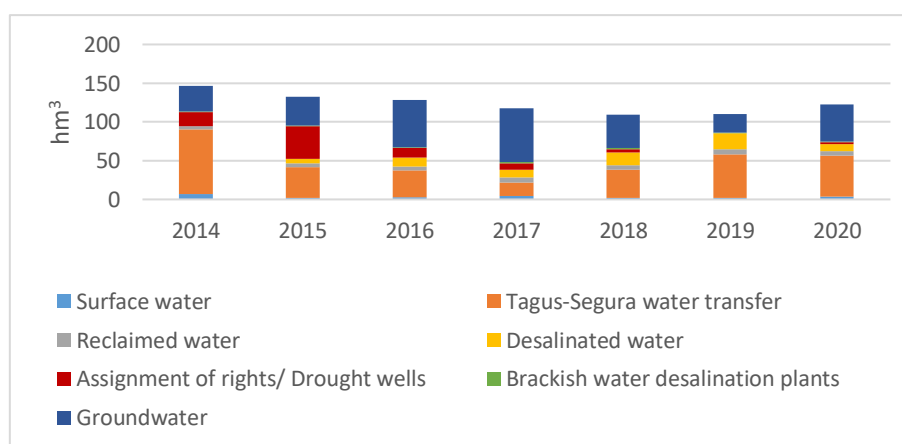


Figure 2. Water irrigation uses by source (2014-2020) for the CRCC. Source: Own elaboration based on data provided by the CRCC.

Despite their strategic importance, NCW are considerably more expensive than conventional sources. Production costs are estimated at €0.44/m³ for reclaimed water and €0.90/m³ for desalinated water (Berbel et al., 2023; Martínez-Alvarez et al., 2023). Public subsidies therefore play a critical role in maintaining affordability. As a result, farmers currently pay €0.085/m³ for reclaimed water and €0.58/m³ for desalinated water, both below production costs.

Table 1. Price of CRCC water sources. Source: Own elaboration

Water sources	Price (€/m ³)
Surface water	0.03
Tagus-Segura water transfer	0.16
Reclaimed water	0.085
Desalinated water	0.58
Assignment of rights/ drought wells	0.14
Brackish water desalination plants	0.1
Groundwater	0.4

Given its dependence on transferred water, growing reliance on NCW, and economic relevance, the CRCC provides an ideal case study for analyzing the impacts of reduced water transfers and the role of alternative water sources in sustaining irrigated agriculture.

METHODOLOGY

Mathematical programming models enable the analysis of agricultural water demand management strategies by integrating economic, agronomic, technological, and institutional constraints (Howitt, 1995). In this study, a model based on the works of Blanco & Viladrich-Grau (2014), Medellín-Azuara et al. (2019) and Escrivá-Bou et al. (2023) has been adapted with specific modifications to evaluate the impact of the TST reduction and alternative water supply scenarios on the CRCC.

Model

The model is initially calibrated to reflect current farmer decision-making under the assumption of profit-maximizing behavior, using the most recent available data, specifically the 2018-2020 average, as the baseline scenario. It maximizes profit by optimizing the use of inputs such as land, water, and labor across various crops, subject to the specific constraints of each scenario (Rodríguez-Flores et al., 2022). The variables in the equations are specified by crop (c: artichoke, broccoli, lettuce-melon, pepper, and lemon tree), month (m), and/or water source (h: surface water, reclaimed water, water rights assignments, groundwater, TST, desalinated water, and brackish water).

This equation shows the profit maximization of farmers:

$$MaxZ = \sum_c (rto_c \times pc_c - cost_c) \times X_c + \sum_c PB_c \times X_c - \sum_m pmo \times MOA_m - \sum_h \sum_m cag_{h,m} \times CostW_{h,m}$$

Where: Z: farm profit; rto_c : yield per crop; pc_c : price per crop; $cost_c$: costs per crop; X_c : production area per crop; PB_c : basic payment (EU Common Agricultural Policy subsidy) per crop; pmo : labor cost; MOA_m : paid labor per month; $cag_{h,m}$: water consumption per month and water source; $CostW_{h,m}$: water cost per month and water source.

This maximization is subject to various constraints, including land availability:

$$\sum_c X_c \leq SAR$$

Where SAR represents the available area in the CRCC. Additionally, Lettuce and melon are planted in succession, which means growing different species in the same space but in different seasons (Poch-Massegú et al., 2014). Conversely, lemon trees and peppers, as a permanent crop and a greenhouse crop, respectively, are restricted to a maximum area variation of 10%, as exceeding this threshold would require costly and complex measures (Sapino et al., 2022; Martínez-Paz et al., 2016).

The constraint of labor:

$$\sum_c NMO_{c,m} \times X_c \leq MOA_m + dMOF_m$$

Where: $NMO_{c,m}$: labor requirements per month and crop; $dMOF_m$: availability of family labor per month. The water constraints:

$$\sum_c NAG_{c,m} \times X_c \leq \sum_h cag_{h,m}$$

$$cag_{h,m} = dag_{h,m} + (dag_{h,m-1} - cag_{h,m-1})$$

Where, $ECW_{h,m}$: salinity of water by source and month. Salinity of irrigation affects crop yields according to the Maas & Hoffman (1977) Model. To mitigate these effects, a salinity threshold of 3 dS/m is set for the water mixture; exceeding this limit results in severe yield restrictions. Next, the calibration constraint equation presented:

$$X_{ct} < X0_{ct} \times (1 + \varepsilon)$$

The calibration constraint equation is included to ensure that the linear programming model reproduces the observed activity levels for the base year ($X0$).

Solving the linear model yields the dual values (μ) associated with the calibration constraints, which provide additional information on the cost functions. From these results, the marginal cost functions are defined according to the parameters:

- α : marginal cost intercept.
- β : marginal cost slope (activity).

$$\alpha_c = cost_c - lr$$

$$\beta_c = \frac{\mu_c}{X0_c}$$

Once the cost functions have been derived, the final nonlinear model is formulated, enabling the simulation of hypothetical agricultural policy scenarios:

$$MaxZNL = \sum_c rto_c \times pc_c \times X_c + \sum_c PB_c \times X_c - \sum_c X_c \times (\alpha_c + 0.5 \times \beta_c \times X_c) - \sum_m pmo \times MOA_m$$

$$- \sum_h \sum_m cag_{h,m} \times CostW_{h,m}$$

This model, which operates without the calibration constraints, accurately reproduces the activity levels observed in the baseline year and serves as the foundation for prospective analyses of agricultural and water policy alternatives.

As noted by Röhm and Dabbert (2003), adopting the simplified quadratic cost function method implies that the same crop grown under two technologies is treated as two separate crops. In our study, however, crops are grown under only one technology. Note that water supply sources are blended by the irrigation district and provided to farmers as a single water source, with its resulting salinity.

Data Collection

The PMP approach is based on secondary data compiled from various sources:

Crop Yield, Area, and Price (CARM, 2024), Crop net water requirements (MAPA, 2024a), Labor requirements (Del Villar García et al., 2020), Basic payment (MAGRAMA, 2016; MAPA, 2022b), Crop salinity thresholds (Maas & Hoffman, 1977), Water source availability from fieldwork conducted in July 2022 and (Soto García, 2020), Water source prices (Soto García, 2020; Soto García, 2015; Custodio, 2018; Custodio et al., 2019) and Water source salinity (Soto García, 2020; Soto García, 2015; Martínez-Alvarez et al., 2023; Sadhwani Alonso & Melián-Martel, 2018).

Scenarios

To assess potential future alternatives, the following scenarios are defined:

- **SCN1_Baseline:** Represents the current situation, based on the average water supply and demand between 2018 and 2020.
- **SCN2_Transf_Red:** Considers a 40% reduction in the TST, as indicated in the SRBMP (CHS, 2022c).
- **SCN3_NCW_Increase:** Builds on the reduced transfer scenario by allowing unrestricted use of desalinated water. Reclaimed water is expanded up to the current concession limit granted to the CRCC.
- **SCN4_NCW_Constraint:** Introduces usage limits on groundwater and desalinated water, as outlined in the SRBMP for 2027, while retaining previous assumptions regarding water transfer and reclaimed water.
- **SCN5_Desal_ReducedPrice:** Maintains the same volumetric constraints as the previous scenario but assumes a reduction in the price of desalinated water to €0.35/m³, following the provisions of Order TED/157/2023. This order temporarily suspends the application of the cost recovery principle (Article 111 bis of the Spanish Water Act) for ten years.
- **SCN6_NCW_FullCost:** Retains the same volumetric constraints but assumes full cost pricing for desalinated and reclaimed water. According to studies by Berbel et al. (2023) and Hurtado & Berbel (2024), these prices could reach €0.90 for desalinated water and €0.44 for reclaimed water.

Table 2. Scenario characteristics. Source: Own elaboration

Scenarios	Availability (hm ³)				Price (€)	
	TST	Groundwater	Desalinated water	Reclaimed water	Desalinated water	Reclaimed water
SCN1_Baseline	48.5	41.4	15.2	6.0	0.58	0.08
SCN2_Transf_Red	29.3	41.4	15.2	6.0	0.58	0.08
SCN3_NCW_Increase	29.3	41.4	unlimited	11.2	0.58	0.08
SCN4_NCW_Constraint	29.3	32.9	44.1	11.2	0.58	0.08
SCN5_Desal_ReducedPrice	29.3	32.9	44.1	11.2	0.35	0.08
SCN6_NCW_FullCost	29.3	32.9	44.1	11.2	0.90	0.44

RESULTS

Table 3 presents the results for each scenario in terms of farm profit, total water use, labor use, and cropping patterns, while Figure 3 illustrates net water use by source under each scenario.

Impacts of Water Transfer Reduction (SCN2_Transfer_Red) A 40% reduction in the TST leads to a

23% decline in total water use. The reduction affects not only transferred water but also the use of groundwater (-6%) and desalinated water (-33%), while increasing the average water cost by 3%, from €0.291/m³ to €0.30/m³, due to the loss of one of the cheapest water sources in the system.

Lower water availability results in a 27% reduction in cultivated area across all crops and a 54% increase in fallow land. Consequently, farm profit decreases by 14%, equivalent to approximately €35 million, while employment falls by 22%, representing more than 3,900 jobs. These results highlight the strong dependence of the CRCC on transferred water and the significant economic consequences of future reductions.

Table 3. Results across scenarios. Source: Own elaboration

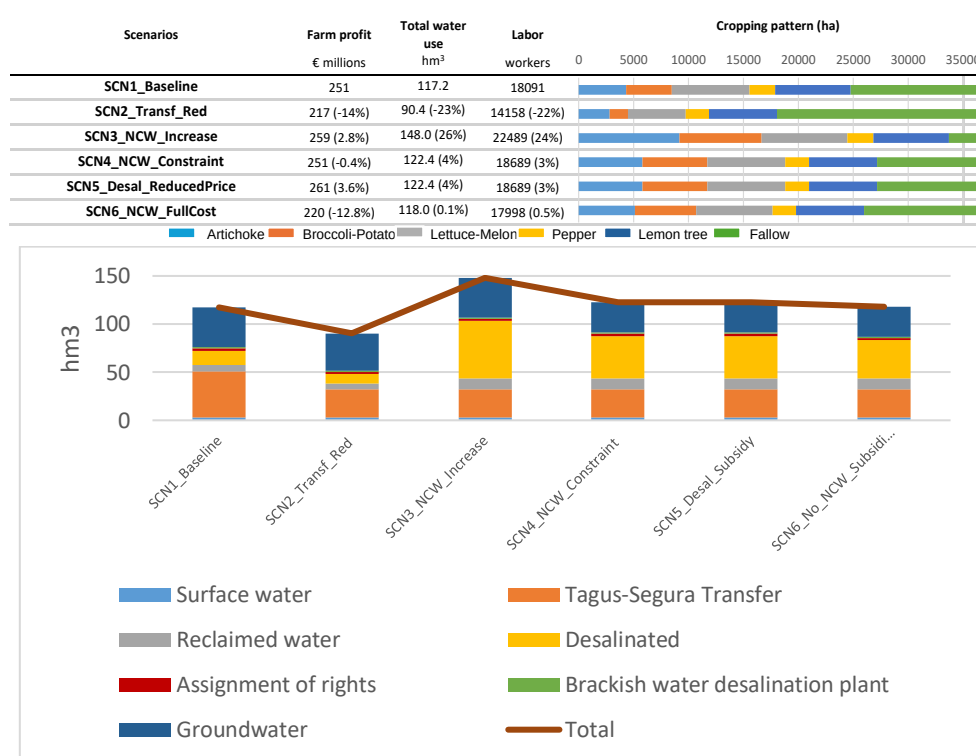


Figure 3. Net water use by source across scenarios. Source: Own elaboration

Impacts of Increased NCW Supplies (SCN3_NCW_Increase)

Allowing unrestricted desalinated water use and expanding reclaimed water to the CRCC's concession limit substantially mitigates the effects of transfer reductions. Reclaimed water reaches 11.6 hm³ and desalinated water use quadruples to approximately 60 hm³, increasing total water use by 26%.

However, greater reliance on desalinated water raises the average water cost by 33%, reaching €0.387/m³. Increased water availability promotes the expansion of nearly all crops, reduces fallow land by 72%, and creates approximately 4,400 additional jobs. Farm profit rises by €7 million, exceeding baseline levels by 2.8%. Despite these positive outcomes, the large increase in desalinated water demand would require major infrastructure investments and higher overall water consumption, raising concerns regarding its long-term sustainability.

Impacts of Constrained Alternative Water Sources (SCN4_NCW_Constraint)

When groundwater and desalinated water use are limited according to the SRBMP targets for 2027, groundwater abstraction decreases by 25%, while desalinated water use increases by 190%, reaching 44.1 hm³. Reclaimed water remains at its maximum concession volume.

Under these conditions, total water use remains close to baseline levels (+4%), although at a higher average cost of €0.362/m³, representing a 24% increase. Most crops expand their cultivated area, fallow land decreases by 19%, and employment increases by approximately 3% (around 600 jobs). Nevertheless, farm profit declines slightly by €1 million (-0.4%), indicating that NCW can largely compensate for reduced transfers, albeit at a higher production cost.

Impacts of a Reduced Desalinated Water Price (SCN5_Desal_ReducedPrice)

Maintaining the same volumetric restrictions as SCN4 while reducing the desalinated water price to €0.35/m³ produces no changes in water use, cropping patterns, or employment because farmers already utilize all available resources. However, the average water cost falls by 4%, increasing farm profit by approximately €9 million relative to the baseline scenario.

Achieving this result would require public subsidies estimated at €10 million to support the consumption of 44 hm³ of desalinated water. Therefore, although lower prices improve profitability, they also imply significant public expenditure.

Impacts of Full Cost Recovery for NCW (SCN6_NCW_Full_Cost)

Under full cost recovery, farmers pay the actual costs of desalinated and reclaimed water. While reclaimed water remains fully utilized, desalinated water use declines slightly due to its higher price. This results in reductions in the cultivated area of artichoke (-12%) and broccoli (-6%), while fallow land increases by 12% and labor demand decreases by 6%. The average water cost rises sharply, more than doubling from €0.291/m³ to €0.597/m³. Consequently, farm profit decreases by €32 million (-13%) compared with the baseline scenario, representing the second-largest economic impact after the transfer reduction scenario.

Analysis of Subsidy Efficiency and Agricultural Profitability

The comparison of scenarios SCN4, SCN5, and SCN6 reveals an important trade-off between agricultural profitability and public expenditure. While lower water prices increase farm profits, they require substantial subsidies. Under SCN5, farm profit reaches €261 million but requires €41.6 million in public support. Compared with SCN6, every additional euro of farm profit generated through subsidies requires approximately €1.01 of public expenditure. These findings suggest that although subsidies can offset profitability losses associated with reduced water transfers, their economic efficiency is limited. Therefore, future water policies should carefully balance agricultural competitiveness, public expenditure, and the long-term sustainability of NCW.

Table 4. Analysis of Subsidy Efficiency and Agricultural Profitability. Source: Own elaboration

Scenario	Farm profit	Profit difference concerning the SCN6	Water cost	Public expenditure	% Public expenditure / farm profit	% Public expenditure/ water cost
	(€ millions)	(€ millions)	(€ millions)	(€ millions)		
SCN4_NCW_Constraint	251	31.3	44.3	31.5	12.6	71
SCN5_Desal_Reducedprice	261	41.4	34.2	41.6	16	122
SCN6_NCW_FullCost	220					

DISCUSSION AND CONCLUSION

Water transfers remain a central element of water management due to their economic, social, and environmental implications (Zhuang, 2016). The anticipated reduction of the TST poses significant challenges for the CRCC, as it reduces water availability, limits the flexibility to combine different water sources, increases average water costs, and leads to substantial reductions in cultivated area (Azorín et al., 2025; Vélez-Nicolás et al., 2020; Martínez-Medina et al., 2024). The results show that these changes negatively affect agricultural profitability and employment, confirming previous studies highlighting the vulnerability of the regional economy to reductions in transferred water volumes (Cañizares et al., 2022).

In line with Morote et al. (2020), greater integration of all available water resources emerges as a key adaptation strategy. Farmers respond to reduced transfers by increasing their reliance on NCW, particularly desalinated and reclaimed water. However, although this strategy helps maintain agricultural production, it also increases water costs and, depending on the cultivated area, may reduce profitability, as these resources are significantly more expensive than conventional water sources (Calatrava & Martínez-Granados, 2012). Reclaimed water is constrained by both limited availability and salinity issues (Gil-Meseguer et al., 2019), while desalinated water, despite its reliability during drought periods, remains highly dependent on public support to be economically viable (Villar-Navascués et al., 2020). The implementation of the new SRBMP in 2027 is expected to intensify this transition by restricting groundwater use and promoting desalination (CHS, 2022a). Although reducing groundwater abstraction may help mitigate aquifer overexploitation, seawater intrusion, and water quality deterioration (Caparrós-Martínez et al., 2020; Mateo et al., 2024), it also increases dependence on a more expensive resource, namely desalinated water, thereby reducing farm profitability (Calatrava et al., 2022; Villar-Navascués et al., 2020).

The results highlight the crucial role of subsidies in supporting the adoption of NCW resources. A reduction in desalinated water prices, as envisaged under Order TED/157/2023, allows farm profits to approach baseline levels while avoiding additional groundwater exploitation. However, these benefits require considerable public expenditure, raising concerns regarding the long-term efficiency and sustainability of such support measures. Indeed, the analysis shows that each additional euro of farm profit generated through subsidies requires approximately one euro of public expenditure. Conversely, when farmers bear the full cost of NCW, desalinated water becomes less affordable, cultivated area declines, and profitability falls significantly. These findings demonstrate that the ability of NCW resources to compensate for reductions in TST supplies largely depends on their cost.

Consequently, future policies should move beyond simple subsidy schemes and consider broader economic, environmental, and social objectives. Cost-sharing mechanisms, such as sanitation fees or user charges, may help distribute the financial burden associated with the development of NCW. Furthermore, reducing energy costs through investments in renewable energy could significantly improve the competitiveness of desalinated water, given that energy accounts for 50–60% of its production costs (Gómez Martínez & Pérez Martín, 2023).

Despite certain limitations related to data aggregation, simplified crop representation, and assumptions regarding future prices and climate conditions, the PMP model provides a useful framework for evaluating water management strategies under changing resource availability conditions.

Overall, the study confirms that reductions in the TST will negatively affect profitability and employment within the CRCC. Nevertheless, alternative water supply strategies can largely compensate for water shortages and maintain agricultural activity. Reclaimed water is constrained by availability and salinity issues, while desalinated water remains costly, although its viability can be improved through subsidies, renewable energy deployment, and the integration of multiple water sources. Therefore, ensuring the long-term sustainability of agriculture in southeastern Spain requires a comprehensive strategy combining expanded desalination capacity, renewable energy investments, integrated water resource management, and policies capable of balancing economic, environmental, and social objectives. This

approach is consistent with current European, national, and basin-level initiatives promoting water reuse, desalination, and more resilient water management.

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