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ORIGINAL ARTICLE

Towards sustainable climate-smart agriculture: A cost–benefit analysis of a modernized irrigation district in Spain

Nicola Comincioli[1,2] | **Cristina El Khoury**[2,3] | **Davide Bazzana**[1,2] | **Demis Legrenzi**[1,2] | **Fernando Nardi**[4,5] | **Daniel A. Segovia-Cardozo**[6] | **Sergio Vergalli**[1,2] | **Leonor Rodríguez-Sinobas**[6]

[1]Dipartimento di Economia e Management, Università degli Studi di Brescia, Brescia, Italy

[2]Fondazione Eni Enrico Mattei, Milan, Italy

[3]Département de Science Politique et Relations Internationales et Institut d'Études de la Citoyenneté (InCite), Université de Genève, Geneva, Switzerland

[4]Dipartimento di Ingegneria Civile e Ingegneria Informatica, Università degli Studi di Roma Tor Vergata, Roma, Italy

[5]Institute of Environment (InWE), Florida International University, Miami, Florida, USA

[6]Escuela Técnica Superior De Ingenieria Agronómica, Alimentaria Y Biosistemas, Ingeniería Agroforestal, Universidad Politécnica de Madrid, Madrid, Spain

Correspondence
Nicola Comincioli, Fondazione Eni Enrico Mattei, Corso Magenta 63, 20123 Milan (MI), Italy.
Email: nicola.comincioli@feem.it

Abstract

Amidst the escalating impact of climate change, the agricultural sector faces the challenge of maintaining productive capacity while conserving increasingly scarce water resources. Modernizing irrigation systems by replacing inefficient open-channel distribution infrastructures is crucial to address this challenge. Cost–benefit analysis (CBA) offers a valuable tool to assess the effectiveness of such actions, in terms of both financial and socio-environmental impacts. CBA is also valuable for optimizing the allocation of lim-

ited financial resources to the most impactful measures and addressing trade-offs within the water-energy-food (WEF) nexus. This study applies CBA to two modernization projects in the 'Villalar de los Comuneros' irrigation district in the Duero River Basin, located in northern Spain. The first project focuses on enhancing energy efficiency by installing a photovoltaic system to power irrigation pumps, while the second promotes climate-smart agriculture through the use of soil moisture sensors to improve irrigation precision and facilitate the transition to higher value crops. The results of the CBA demonstrate the financial and economic viability of both projects, highlighting the social and environmental benefits generated, and providing policymakers with a valuable framework for guiding similar future interventions.

KEYWORDS
cost–benefit analysis, Climate-smart agriculture, water–energy–food nexus

JEL CLASSIFICATION
D61; D62; Q51

1 | Introduction

The Duero River Basin (DRB) is located in the northern part of the Iberian Peninsula and stretches between Spain and Portugal. It has always been vital for local communities in both countries, providing essential resources for agriculture and energy production. In recent years, however, freshwater availability has significantly declined as well as in the whole Mediterranean region, and projections indicate further reductions in the future (Hierro, 2024). This growing water scarcity, resulting in droughts and water insecurity, is driven primarily by climate change and inadequate water management practices (Bazzana et al., 2023; Gomez et al., 2004). In this context, the increased frequency and severity of droughts highlighted the need for more efficient water management strategies and infrastructures to ensure the sustainable use of water resources (Borrego-Marín & Berbel, 2019). In response to these challenges, the 'River Duero Basin Management Plan (2022–2027)' was released, emphasizing the importance of an effective water management strategy, as a key pillar for climate change adaptation.

Decisions concerning the future of hydrological infrastructure, particularly regarding irrigation schemes, can have significant impacts on the well-being of local communities. In the DRB, as in the rest of Spain and the broader Mediterranean region, a wide range of stakeholders face significant water management challenges, due to rising temperatures (Sordo-Ward et al., 2020),

unpredictable precipitation patterns (Lorenzo & Alvarez, 2020), and increasing water demand (Espinosa-Tasón et al., 2020). Modernizing irrigation schemes is therefore essential to ensure sustainable agricultural productivity, especially in light of the historically complex interplay among water resources, energy and agricultural production. In response to these challenges, the water–energy–food (WEF) nexus has emerged as a guiding framework for the integrated sustainable management of these interconnected resources, recognizing their mutual linkages as critical for efficient resource governance and sustainable development (Hellegers et al., 2008; Lee & Ellinas, 2010). The concept of the WEF nexus first appeared in 2008 (Hellegers et al., 2008) and was further improved and elaborated following the Bonn 2011 Conference 'The Water Energy and Food Security Nexus – Solutions for the Green Economy' (Hoff, 2011; Keskinen & Varis, 2016), into a strategic framework to promote integrated and cross-sectoral resource governance. It emphasizes the growing interdependency between water availability, energy demand, and agricultural productivity, which should be explicitly identified in decision-making processes. In agricultural settings such as the DRB, recognizing these connections allows for synergies that, if properly exploited, could mitigate trade-offs while improving the efficiency of resource use. By adopting a WEF nexus perspective, previously uninvolved stakeholders can collaborate more effectively, gaining valuable insights about resource scarcity mitigation strategies and conflict resolution (Bakker & Morinville, 2013; Scott, 2017). In this context, this paper offers an innovative application of cost–benefit analysis (CBA) grounded in the WEF approach, explicitly adhering to the European Commission's (EC) guidelines for evaluating investment projects (Comincioli et al., 2024; European Commission, 2022).

This study investigates the potential benefits arising from two different actions related to irrigation modernization in the DRB, through a comprehensive approach that integrates WEF nexus principles to enhance resource efficiency and resilience. Both actions were designed and planned by the relevant stakeholders, specifically the agricultural entrepreneurs operating in the area covered by this study. The first intervention involves the installation of photovoltaic (PV) panels to power irrigation pumps. This type of intervention is intended to reduce grid dependency, which is heavily reliant upon non-renewable energy sources while lowering greenhouse gas (GHG) emissions. Solar-powered irrigation systems offer therefore a sustainable energy solution, aligning with Spain's broader renewable energy goals and strengthening energy security in the agricultural sector (IEA, 2021). The second intervention focuses on the adoption of climate-smart agriculture (CSA) practices. More specifically, the use of advanced soil moisture sensors, enabling precise monitoring and management of soil water content, weather conditions and crop needs, is analysed. Thanks to the improved irrigation efficiency allowed by this intervention, crop resilience to climatic stresses is enhanced, enabling the introduction of new, higher value crops.

This paper aims to contribute to the scientific literature in several ways. First, to the best of our knowledge, it presents the first application of CBA within the WEF nexus, explicitly aligned with the EC's guidelines for evaluating investment projects. Second, it introduces a novel conceptual approach within CBA, allowing for a rigorous estimation of avoided emissions based on carbon pricing within the EU Emissions Trading System (EU ETS) market (Borghesi et al., 2025). Third, through a detailed case study of irrigation system modernization in the DRB, this paper provides a comprehensive assessment of its long-term financial and socio-economic viability. Indeed, we demonstrate how WEF-focused actions, such as PV installations, soil moisture sensors and crop diversification, are not only financially sustainable but also generate significant socio-environmental benefits, whether considered individually or collectively. By adopting a WEF nexus perspective, this study underlines the interdependencies and synergies between water management, energy use and agricultural productivity, core pillars of the 2030 Agenda for sustain-

able development. In doing so, it directly contributes to several Sustainable Development Goals (SDGs), mainly SDG 6 (clean water and sanitation) and SDG 7 (affordable and clean energy). Furthermore, by promoting SDG 8 (decent work and economic growth), through the easing of resource constraints in communities within the irrigation district, the research also supports the achievement of SDG 2 (zero hunger). We demonstrate that actions aimed at improving WEF efficiency are not only financially sustainable but also generate positive social and environmental spillovers enhancing the overall desirability of such investments. Finally, by proposing a structured policy-relevant analytical framework, this study could serve as a standardized *vademecum*, compliant with the EC guidelines (European Commission, 2022) to evaluate the costs and benefits of WEF-related agricultural modernization interventions. In the broader context of global climate change and increasing competition among alternative uses of natural resources, this study provides valuable insights for stakeholders and policy-makers to optimize the allocation of scarce financial resources to projects that promote agricultural productivity in a sustainable, resilient and effective way.

The rest of this article is structured as follows. Section 2 reviews the literature on CSA, identifying the existing gaps that this study seeks to address. Section 3 outlines the intervention strategy in the DRB and describes the irrigation consortium in the municipality of Villalar de los Comuneros, where investigated actions take place. Section 4 details the CBA methodology adopted, while Section 5 presents and discusses the main findings. Finally, Section 6 concludes and presents final remarks and policy implications.

2 | LITERATURE REVIEW

With the global population expected to rise significantly in the coming years, and resources becoming increasingly scarce, meeting the growing demand for food will be a major challenge for the agri-food industry, especially given the limited availability of agricultural land (Mizik, 2021). This situation highlights the urgent need for a fundamental transformation of agricultural practices to maximize production efficiency using the scarce resources available, particularly within the WEF nexus.

In this context, the concept of CSA has been the subject of extensive study as a means of enhancing agricultural resilience and sustainability. Studies by Mutenje et al. (2019) and Branca et al. (2021), have shown that the integration of CSA practices, for example, crop varieties improvement, soil conservation and minimal soil disturbance, can generate significant economic and environmental benefits for small-scale farmers in regions such as Malawi, Mozambique and Zambia. These practices enhance resource efficiency and contribute to more sustainable agricultural systems. The role of CSA in risk mitigation and productivity enhancement in the African context has been widely discussed (Nyasimi et al., 2017; Zerssa et al., 2021), while crop diversification and agroforestry have proven to be effective strategies for mid-hill farmers in Nepal, showcasing regional variations in CSA application (Adhikari, 2018). In addition, the adoption of sustainable land management practices is expected to improve both productivity and environmental performance at the small-scale farming level (Siedenburg et al., 2012). Several studies reveal a number of positive outcomes associated with CBA in a variety of geographical regions. For example, studies conducted in Nepal's Gandaki River Basin reveal that the majority of CSA practices, including improved crop varieties and sustainable soil management, are economically viable. However, certain practices present lower returns due to extended payback periods (Poudel et al., 2024). Similarly, research in Guatemala's Dry Corridor emphasizes the economic viability of the majority of CSA options

yet also reveals the potential risks associated with specific drought-resistant practices (Sain et al., 2017). In sub-Saharan Africa, good agricultural practices, conservation agriculture and improved seed varieties have been identified as the most promising CSA interventions, with significant benefits for smallholder farmers across multiple value chains (Akinyi et al., 2022).

Despite the high vulnerability of the Mediterranean region to climate change, there is a lack of studies focusing on CSA and its associated CBA in this area. This lack of research contrasts with the extensive coverage of CSA in African and Asian regions, highlighting a critical gap in the literature that needs to be addressed, in light of the unique challenges faced by Mediterranean agricultural systems (Mizik, 2021). Indeed, in Mediterranean countries agriculture has evolved under the principle of achieving high productivity with little water, which is why traditional cereal crops, olive trees, and vineyards are, for the most part, tolerant to drought stress, having adapted to the long, dry seasonal periods characterizing the region (García-Ruiz et al., 2011). However, future projections indicate that increased water demand and decreased precipitation will likely exacerbate the instability of water resources (Iglesias et al., 2011). As a result, there is an urgent need for crop adaptation and the development of innovative technologies to enhance water productivity and mitigate the adverse impacts on farmers.

While some aspects of CSA are well-documented, there are significant gaps in understanding contextual factors and the role of public–private partnerships (Totin et al., 2018). Indeed, despite the acknowledged importance of irrigation systems for crop productivity and the role of policy for adaptation and food security (Rinaldi et al., 2001), empirical research in this area remains limited. Most existing CSA studies focus on rain-fed, small-scale farming systems and often neglect the complexities involved in modernizing irrigation infrastructure within the WEF nexus. Furthermore, the topic of the financial and economic viability of integrating CSA practices with modern irrigation technologies is still under investigation. A CBA-compliant viability assessment could shed light on the benefits of such integration.

3 | SITE DESCRIPTION AND INTERVENTION STRATEGY

This study focuses on the irrigation district of 'Villalar de los Comuneros Sector I', which has a surface of 517 ha[1] and is located within the DRB in the region of Castilla y León in north-western Spain (Figure 1). The climate in the region is continental Mediterranean, characterized by long and cold winters (average temperatures between 3 and 6°C), and short, hot summers (average temperature from 19 to 22°C). Rainfall is scarce, averaging between 400 and 500 mm per year (Nafría et al., 2013). Nonetheless, climate variability over the past decades, particularly with regard to rainfall, has reduced water availability for irrigation. This decline poses a permanent threat to farmers, who are increasingly unable to cultivate the whole irrigated surface (Segovia-Cardozo et al., 2019).

The study area is located in the 'Bajo Duero' sub-basin, in the centre of the Duero sedimentary basin, between geographic coordinates N41°33′51″, W5°9′7″ and N41°32′14″, W5°6′41″, at an altitude of almost 700 m a.s.l., where the most frequent soil textures are loamy clay sand or sandy loam (Nafría et al., 2013). The irrigation district uses groundwater for irrigation, which is extracted from an underground aquifer through nine wells, each with an average depth of

[1] For the purposes of the calculations presented, an area of 496.3 ha is considered. This figure accounts for (i) the requirement of the common agricultural policy strategic plan, which mandates that at least 4% of agricultural land be left fallow to support green deal targets (European Commission, 2023) and (ii) approximately 12 ha allocated to non-productive uses.

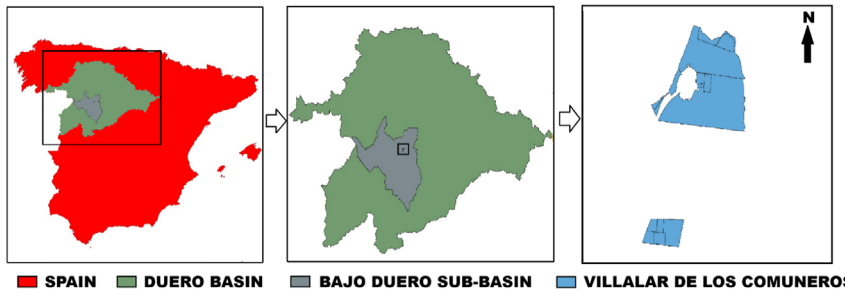

FIGURE 1 Position of the irrigation district object of this study within the DRB and its location in Spain. [Colour figure can be viewed at wileyonlinelibrary.com]

250 m. The extracted water is then directed to a surface regulation reservoir with a maximum storage capacity of 58, 746 m^3. From there, the water is pumped through an irrigation network to the various users. The maximum extraction allowed by the basin resource management entity is 8, 294.4 m^3 ha^{-1} $year^{-1}$. As there is no power generation in the irrigation district, the energy required for the operation is supplied by third parties, and the average yearly energy consumption is around 801 MWh.

3.1 | Action 1: Energy efficiency

One of the most widely used methods for sustainable electricity generation is represented by PV plants. The adoption of this technology plays a critical role in mitigating climate change, reducing GHG emissions and decreasing dependence on the grid, in turn often very reliant upon non-renewable energy sources. Indeed, PV investment not only promises substantial environmental benefits but also represents a significant opportunity for economic recovery and growth (Segura et al., 2023). Aligned with the objectives of the National Integrated Energy and Climate Plan (NIECP) 2021–2030, the Spanish PV sector has the potential to become a cornerstone of the country's energy strategy. The NIECP outlines actions necessary for the efficient use of clean energy, aiming to foster economic growth, create employment opportunities, improve public health and protect the environment. By investing in PV technology, Spain is enhancing its energy security, reducing energy costs, and stimulating innovation and technological advancements within the renewable energy sector (IEA, 2021).

More in detail, the first action under study involves investing in a PV system with an installed capacity of approximately 90 kW, as proposed by the project stakeholders. This plant will be strategically located in the municipality and will supply the electricity needed for the local pumping systems, with PV panels mounted on fixed racks. Given the absence of specific quotas, the cost estimation is based on similar case studies in the literature. Estimates of a PV plant with similar features and location as the one considered here imply an initial cost of approximately 800 thousand euros per MW of installed capacity (Pérez & Alonso-Montesinos, 2023). Thus, the cost for a 90 kW installation is roughly 72 thousand euros Additionally, the maintenance expenses are estimated to be around 8 thousand euros per MW $year^{-1}$ (Pérez & Alonso-Montesinos, 2023), resulting in annual operations and maintenance (O&M) costs of approximately 720 euros for the 90 kW plant. This analysis assumes that the plant is fully financed, thereby excluding any external financial costs.

TABLE 1 Monthly and yearly average irradiation and corresponding electricity generation, electricity consumption, cost, and water delivered.

Month	Solar radiation ($kWh/m^2/day$)	AC production (MWh)	AC consumption (MWh)	Cost (MWh)	Water ($m^3 \times 10^3$)
January	2.01	4.77	10.9	2.71	–
February	3.21	6.75	14.19	3.53	–
March	4.58	10.53	11.43	2.84	–
April	5.32	11.61	14.83	3.69	–
May	6.19	13.68	96.87	24.10	–
June	6.83	14.31	182.95	45.52	722.44
July	7.51	16.02	204.24	50.82	200.92
August	7.16	15.39	163.99	40.80	150.31
September	5.59	11.88	54.70	13.61	131.49
October	4.04	9.18	18.06	4.49	–
November	2.50	5.58	12.40	3.08	–
December	1.71	4.05	16.81	4.18	–
Year	**4.72**	**123.75**	**801.37**	**199.39**	**1,205.15**

Source: https://pvwatts.nrel.gov.
Abbreviation: AC, alternating current.

In order to estimate the expected alternating current (AC) output from the installation of the PV plants, the National Renewable Energy Laboratory (NREL) PVWatts calculator is employed (Dobos, 2014). We set this tool to use irradiance and meteorological data from the city of Valladolid, which is considered a representative location for the PV plant.[2] By incorporating local solar radiation levels and weather conditions, the PVWatts calculator provides a realistic projection of the plant's energy output. Table 1 presents the monthly estimates of solar radiation at the specified location alongside the corresponding AC production. The table also includes the irrigation consortium's average data on electricity consumption, the cost of purchasing electricity from the market, and the amount of water delivered to the fields.

3.2 | Action 2: Water and food efficiency

The second action under study encompasses two coordinated measures aligned with the principles of CSA. According to the Food and Agriculture Organization (FAO), CSA relates to agriculture that sustainably increases productivity, enhances resilience, reduces GHG emissions, and facilitates the achievement of national food security and development (Lipper et al., 2017). Given the far-reaching impacts of climate change on global food security, the CSA is emerging as a promising solution, advocating a transformative shift towards innovative practices and technologies that not only boost agricultural productivity but also build resilience to climate change, and reduce GHG emissions (Karlsson et al., 2018). By recognizing the multifaceted challenges posed by climate change and taking proactive measures, CSA offers a pathway to food security for the world's population.

[2] Estimates were obtained by setting the PV nominal efficiency to 19%, inverter efficiency to 96% and system losses, due to factors such as panel degradation and connection resistivity, to 8.7%

In Spain, the modernization of irrigation and water management systems gained significant momentum during the droughts of the 1990s (García et al., 2014). This was followed by a regulatory and economic effort by the Ministry of Agriculture, culminating in the launch of a National Irrigation Plan (NIP) in 2001 (Barbero, 2006). The NIP aimed to transform Spain's predominantly open-channel distribution-based irrigation system into a more efficient, pressurized closed system (Borrego-Marín & Berbel, 2019). At the site of interest, a series of investments to modernize water management began even before the release of the NIP. In fact, since 1987, a cumulative total of 4.48 million euros has been invested,[3] primarily for the installation of concrete pressure pipes, pumping systems, electrical equipment and wiring, as well as the construction of an artificial reservoir. Therefore, in the present day, the final step needed to complete the transition to CSA and maximize water use efficiency is the installation of soil moisture sensors, as advocated by stakeholders. These sensors enable precise monitoring of soil moisture levels, allowing for informed decision-making regarding irrigation scheduling and pump utilization. The installation process for these sensors is relatively straightforward, enabling monitoring at different soil depths. The primary goal of using these sensors is to accurately estimate the amount of water entering the soil-plant system at any given moment, thereby preventing large water losses or undesirable water deficits (Berbel & Montilla-López, 2019). In addition, the key advantage of these probes from an irrigation management standpoint is their ability to collect data almost continuously. For optimal and automated irrigation management, stakeholders propose installing one sensor at each of the 96 irrigation hydrants. Each sensor, including installation expenses, has an approximate cost of 2.5 thousand euros (Ferrer et al., 2010), leading to a total investment of 240 thousand euros for the complete system.[4]

The installation of soil moisture sensors marks the completion of the irrigation system modernization process that began in 1987, leading to two main outcomes: (i) a significant reduction in water and fertilizer usage per unit of yield and (ii) the potential introduction of new crops that could not be cultivated before the investment. However, one clarification is crucial at this point: the installation of the sensors alone would not have led to the benefits, in terms of water and fertilizer savings, discussed later, as well as the wider choice of crops. Indeed, these achievements have also been made possible by the investments described above which, starting from the late 1980s, enabled the gradual modernization of the irrigation system. For this reason, assigning the entirety of the benefits to the installation of sensors alone may be misleading. Rather than attributing all effects to the sensor installation, we instead adopt a more conservative approach by assigning only a portion to it. More specifically, for this purpose, we use the share of the cost of sensors relative to the total expenditure for irrigation modernization since 1987, at present values. This share is equal to 5.09%.[5]

In terms of water use reduction, following soil moisture sensors a 25% decrease is expected (Ferrer et al., 2010; Martínez-Gimeno et al., 2020). The benefits of adopting water-conserving and water-saving technologies extend beyond mere water savings. In fact, a 10% reduction in fertilizer costs is also expected (Borrego-Marín & Berbel, 2019), extending the environmental benefits of

[3] Figure adjusted to 2024 values. The conversion was based on historical CPI trends in Spain, see: statista.com, and the projections by the International Monetary Fund for 2024 (IMF, 2024).

[4] Also in this case, we assume an immediate full payment, hence avoiding further financial costs. For further details, see https://sentektechnologies.com/products/soil-data-probes/drill-drop/.

[5] Additional discussion about the rationale of this choice, as well as concerning alternative attributions of benefits, is provided in Appendix A.

TABLE 2 Information of current and future crops in the irrigation district: area currently cultivated, water and fertilizer requirements and corresponding cost, expected yield and average wholesale market price.

		Water			Fertilizer		Yield	
	Surface	Required		Total cost	Required	Total cost	Quantity	Price
Crop	(ha)	(mm)	(m^3/ha)	(EUR)	(kg/ha)	(EUR)	(kg/ha)	(EUR)
Barley	101.00	138.60	1,386.01	23.16	313.10	12.65	5,421.00	0.82
Wheat	82.44	280.26	2,802.59	38.23	444.00	14.64	4,445.50	0.32
Poppy	19.39	337.65	3,376.51	10.83	120.00	0.93	4,050.00	0.28
Carrot	–	341.00	3,410.00	–	429.00	–	30,400.00	0.86
Onion	–	450.00	4,500.00	–	623.00	–	12,000.00	1.62
Alfalfa	77.81	636.12	6,361.23	81.89	33.63	1.05	11,000.00	–
Sunflower	37.90	393.68	3,936.76	24.68	120.00	1.82	2,745.00	2.14
Peas	32.45	129.98	1,299.80	6.98	80.00	1.04	3,153.00	2.57
Beets	30.49	1,232.29	12,322.95	62.17	629.00	7.67	103,541.00	0.61
Corn	22.41	765.24	7,652.43	28.37	971.00	8.70	13,840.00	0.43
Colza	19.32	458.82	4,588.18	14.67	100.00	0.77	3,700.00	0.55
Rye	19.25	270.3	2,703.04	8.61	150.00	1.15	5,352.00	2.58
Canola	12.74	75.03	750.30	1.58	100.00	0.51	3,584.00	1.93
Grass-Alfalfa	11.71	540.41	5,404.14	10.47	–	–	27,500.00	–
Rape	10.41	331.29	3,312.86	5.71	250.00	1.04	45,000.00	–
Orchard-Alfalfa	4.18	162.64	1,626.40	1.13	303.00	0.51	–	–
Trees	2.93	40.74	407.43	0.20	–	–	–	–
Total/Average	**484.44**	**397.6**	**3,975.96**	**318.67**	**270.86**	**52.49**	–	–

Note: The relevant crops for CBA purposes are only the first five since no change in crop area is expected for the others. Costs and prices are expressed in thousands of euros.

these measures. By reducing water and fertilizer use, more sustainable agricultural practices are promoted, improving overall resource efficiency.

Regarding the potential crop change, the water availability from the artificial reservoir, combined with the efficient use enabled by the pressure pipe system and soil moisture sensors, allows for the introduction of higher value crops that were previously impossible to harvest, thus increasing diversification. The action under study aims to further enhance agricultural sustainability and resilience, aligning with the principles of CSA. Table 2 represents the agricultural situation of the irrigation district, with water and fertilizer needs, corresponding costs, and yield for the planted crops. For example, barley and wheat, which are now predominant crops, require a large amount of water and fertilizer, resulting in considerable costs. In order to address these resource challenges through the implementation of CSA practices, a strategic increase of the area devoted to poppy (*Papaver somniferum* L.) and the introduction of carrot (*Daucus carota* L.) and onion (*Allium cepa* L.) cultivation are proposed, each covering an additional 50 ha. Shifting cultivation to these crops, while introducing the soil moisture sensors, will reduce overall input costs while maintaining or increasing yield value. This approach not only aligns with CSA principles but also helps build resilience, reducing the risk of food insecurity and enhancing the adaptive capacity to cope with the challenges posed by climate change (Lipper et al., 2014).

4 | METHODOLOGY

The CBA on the two actions described in Section 3 is executed in compliance with the EC's guidelines for the evaluation of investment projects (European Commission, 2022, 2014). Accordingly, a financial analysis and an economic analysis are carried out for both actions. In addition, we conducted a set of sensitivity analyses to test the robustness of our results to variations in discount rates. These additional results are presented and commented on in Appendix B (Tables B.1–B.4).

Financial analysis

The aim of financial analysis is to evaluate the financial profitability and sustainability of an investment project. For this purpose, all cash flows generated, for example, investment, replacement and operating costs, revenues and residual value, are evaluated under a discounted cash flows approach to obtain a net present value (NPV), defined as

$$NPV = \sum_{t=0}^{T} CF_t (1 + FDR)^{-t}, \tag{1}$$

where CF_t is the net cash flow at time t, which is discounted using the financial discount rate (FDR) between the present day and T. A positive financial NPV indicates that the project is profitable and therefore does not need financial support and vice versa (Jenkins & Harberger, 2018).

While the cash flows are specific to each of the two actions and will be detailed in Section 5, the choice of the time horizon and FDR applies equally to both cases and is therefore discussed here. The choice of the time horizon has major implications because investment costs are concentrated in the first year(s), while benefits tend to materialize more gradually and persist over a long period. Some scholars suggest that the impact of the chosen time horizon on the final results is more relevant compared to that of the discount rate (O'Mahony, 2021). EC guidelines suggest specific time horizons for a wide range of projects, never exceeding 30 years (European Commission, 2014). In this analysis, we choose a conservative approach and set $T = 25$ years. Then, the FDR represents the opportunity cost of directing financial resources to the specific project analysed. For this reason, this rate is approximated by the return on an investment with a similar risk profile. For this purpose, we rely on the value recommended by the European guidelines, that is, $FDR = 4\%$ (European Commission, 2022), as a baseline value. Moreover, in the sensitivity analysis provided in Appendix B, we test two additional levels in order to check the robustness of our findings. On the one hand, being the recommended value slightly lower than those used in literature for Southern Europe studies, which ranges between 5% and 8% (Florio, 2006), we use a higher (h) value $FDR_h = 6\%$. On the other hand, we also test a lower (l) level, namely $FDR_h = 2\%$.[6] Table 3 summarizes the values of the parameters used.

Economic analysis

The financial NPV provides only a partial view because it solely accounts for actual cash flows valued at market prices. Hence, the net social benefit (NSB), also known as economic NPV, should

[6] In this study, given the relatively short time horizon, we consider constant discount rates. However, in scientific literature dealing with investments generating benefits for generations, time declining discount rates are often used, to avoid the underestimation of future benefits (Nesticò et al., 2023).

TABLE 3 Parameters adopted for the CBA.

Parameter		Value(s)	
		Baseline	Sensitivity analysis
Time horizon	T	25 years	–
Financial discount rate	FDR	4.00%	6.00%, 2.00%
Social discount rate	SDR	3.00%	4.00%, 2.00%
Prices conversion factor	CF_p	90.00%	–
Wages conversion factor	CF_w	79.00%	–

Note: For each parameter, we show the baseline value along with the values tested with sensitivity analysis (when applied).

be computed by adjusting the NPV to include non-market impact generated by considered investments, discounted using the social discount rate (SDR) (European Commission, 2022; Feldstein, 1964). In addition to those non-market impacts that can only be evaluated qualitatively, those that can be assessed quantitatively are generally categorized into (i) supply chain and employment effects and (ii) social and environmental externalities, with the latter being particularly relevant to the current analysis (Castro et al., 2024).

The analysis of supply chain and employment effects is typically based on the so-called shadow prices and shadow wages, instead of market prices for goods, services and labour (European Commission, 2014).[7] The EC guidelines recommend the use of shadow prices because they can reflect the real economic value by adjusting for distortive effects induced by, for example, tariffs, taxes and undeclared work, hence providing a better picture of the opportunity cost of goods and services. For this purpose, all cash flows must be corrected by a country-specific conversion factor (CF), which differs for tradable goods or services prices (CF_p) and wages (CF_w). They are defined as:

$$CF_p = \frac{X + M}{X + M + T_m - S_m}, \quad CF_w = (1 - r)(1 - u), \tag{2}$$

where X is the total export value, expressed in cost insurance and freight prices, M is the total import value in free on board prices, T_m and S_m are import tax and subsidies, respectively, r is the average income taxation and u is the local unemployment rate.

Thus, the NSB of an investment project can finally be defined as

$$NSB = \sum_{t=0}^{T} (SCF_p \cdot P_t + SCF_w \cdot W_t + E_t)(1 + SDR)^{-t}, \tag{3}$$

where P_t, W_t and E_t are the cash flows generated at time t by the purchase or sale of goods or services, wages payment and externalities, respectively. These values are discounted using the SDR until time T. In the case of prices and wages, cash flows are adjusted using the corresponding CFs.

Although these actions generate both cash flows and externalities for an indefinite period of time, we conservatively align the time horizon of the economic analysis with that of the financial analysis. However, the discount rate used in economic analysis is different. Indeed, the SDR

[7] The scientific literature proposes alternative approaches to evaluate employment effects, despite not being applicable in a CBA framework. One common method involves input–output models, which compute locally defined and industry-specific multipliers (Leontief, 1986). These multipliers quantify the effect that an investment in a specific sector generates on the whole economy.

'*reflects the social view on how future benefits and costs should be valued against present ones*' (European Commission, 2014, p. 55). Thus, we adopted the SDR baseline value of 3% suggested by the EC guidelines (European Commission, 2022). However, to enhance the resilience and reliability of our findings, we performed a sensitivity analysis using two alternative SDR values, detailed in Appendix B. The higher (h) value is suggested by the literature with specific reference to water resources project evaluations in Spain (Florio, 2006), namely $SDR_h = 4\%$. The lower (l) value we test is instead $FDR_l = 2\%$. Finally, for what concerns CFs in Spain, we use $CF_p = 90\%$ to correct prices (Ortuño et al., 2022) and $CF_w = 79\%$ to adjust wages (Markanday et al., 2021). The parameters used in economic analysis are summarized in Table 3.

5 | RESULTS

5.1 | Action 1: Energy efficiency

Financial analysis

The results of the financial analysis of the PV plant installation are reported in the upper part of Table 4.[8] As described in Section 3.1, cost items associated with this action pertain to installation and maintenance. Given the installed PV capacity of 90 kW, these costs are quantified as 720 thousand euros for installation and 720 euros per year for O&M. The financial benefit generated by this action is represented solely by the value of the electricity produced. Given the size of the plant considered and the average consumption of the irrigation system, detailed in Table 1, excess production is never achieved and, as a consequence, no electricity is sold on the market. Therefore, the financial benefit is limited to the savings derived from self-consumption, evaluated at market price.[9] The amount of these savings is quantified using the production values shown in Table 1, along with a simulation of electricity market prices in Spain produced by Oxford Economics.[10]

These results indicate that this investment is financially viable on its own. Over the 25-year horizon and applying a financial discount rate of 4%, the NPV is approximately 148 thousand euros. In addition, the break-even point is reached in approximately 6 years. This finding is in line with the relevant literature, which indicates that the payback period for PV plants of similar size typically falls between the fourth and fifth year (Sumper et al., 2011).

Economic analysis

The NPV described above is now adjusted to become an NSB, following the methodology outlined in Section 4. The lower part of Table 4 shows the results of economic analysis. To calculate the NSB, we first determine the share of each cost item related to purchases and wages, respectively. This is possible by investigating the cost breakdown of PV systems. Specifically, it is estimated that for a community solar model with a size between residential PV and utility PV, an average of 29.5% of installation cost can be attributed to labour costs (Ramasamy et al., 2023), while wages represent about 20.9% of O&M costs (Enbar et al., 2016). By applying the proper CFs to the

[8] All results of this study are shown at the annual level for sake of brevity. Instead, calculations have been performed at the monthly level. Full details are available upon request.

[9] It is worth noting that, in compliance with the Royal Decree 900/2015 and modified by Royal Decree-Law 15/2018 regulating the electric self-consumption, installations with capacity below 100 kW are not eligible for compensation for overproduction discharged into the grid (Escobar et al., 2020).

[10] See: https://www.oxfordeconomics.com.

TABLE 4 Details of financial analysis and resulting NPV (above) and those of economic analysis and corresponding NSB (below) of Action 1 (Energy efficiency).

	Total 2024	Year 0 2024	Year 1 2025	Year 2 2026	Year 3 2027	… …	Year 25 2049
Financial analysis							
PV Installation	−72.00	−72.00	0.00	0.00	0.00	…	0.00
	(−72.00)	(−72.00)	(0.00)	(0.00)	(0.00)	…	(0.00)
PV O&M	−11.25	0.00	−0.69	−0.67	−0.64	…	−0.27
	(−18.00)	(0.00)	(−0.72)	(−0.72)	(−0.72)	…	(−0.72)
AC Production	230.80	0.00	15.14	13.63	13.01	…	6.47
	(374.00)	(0.00)	(15.75)	(14.74)	(14.64)	…	(17.25)
NPV (FDR = 4.00%)	**147.55**	−72.00	**14.45**	**12.96**	**12.37**	**…**	**6.20**
Economic analysis							
PV installation shadow cost	−45.68	−45.68	0.00	0.00	0.00	…	0.00
	(−45.68)	(−45.68)	(0.00)	(0.00)	(0.00)	…	(0.00)
PV installation shadow wage	−16.78	−16.78	0.00	0.00	0.00	…	0.00
	(−16.78)	(−16.78)	(0.00)	(0.00)	(0.00)	…	(0.00)
PV O&M shadow cost	−8.93	0.00	−0.50	−0.48	−0.47	…	−0.24
	(−12.82)	(0.00)	(−0.51)	(−0.51)	(−0.51)	…	(−0.51)
PV O&M shadow wage	−2.07	0.00	−0.12	−0.11	−0.11	…	−0.06
	(−2.97)	(0.00)	(−0.12)	(−0.12)	(−0.12)	…	(−0.12)
AC Production shadow benefit	232.17	0.00	13.76	12.50	12.06	…	7.41
	(336.60)	(0.00)	(14.17)	(13.27)	(13.17)	…	(15.52)
Externality carbon	67.41	0.00	2.19	2.28	2.37	…	1.67
	(100.88)	(0.00)	(2.26)	(2.42)	(2.59)	…	(3.50)
NSB (SDR = 3.00%)	**226.12**	−62.46	**15.34**	**14.19**	**13.85**	**…**	**8.78**
|Benefit/cost|	**4.08**						

Note: All values are expressed in thousands of euros. Non-discounted values are shown in brackets.
Abbreviations: AC, alternating current; FDR, financial discount rate; NPV, net present value; NSB, net social benefit; O&M, operations and maintenance; PV, photovoltaic; SDR, social discount rate.

resulting shares of prices and wages, that is, $CF_p = 90\%$ and $CF_w = 79\%$, respectively, shadow prices and shadow wages are immediately derived. The same procedure is also used for financial benefit, where only the CF_p is applied to correct for market distortions. Additionally, externalities must be considered to fully capture the broader societal impacts of the investment. There is a wide consensus about the relevance of PV plants' externalities, often recognized as important advantages of this technology, especially at an early stage when the sector is not fully developed (Wu et al., 2016). Besides those externalities that can only be evaluated qualitatively, such as improvement in system reliability and reduction of distribution losses, the effects that can be quantified are typically represented by (i) supply chain and employment effects, (ii) the possibility of self-consumption, and (iii) avoided emissions (Castro et al., 2024). Following the EC guidelines on CBA (European Commission, 2014), the first effect is accounted for by the use of specific CF. On the other hand, savings in electricity purchase due to (partial) self-consumption have already

TABLE 5 Carbon intensity of different generation technologies and their distribution in Spain in 2023.

Source	Carbon intensity (kg/kWh)	Share (%)
Wind	0.01	23.46%
Nuclear	0.01	20.34%
Gas	0.44	17.54%
Solar	0.04	15.75%
Hydro	0.02	11.42%
Other fossil	1.11	8.37%
Other renewables	0.02	1.67%
Coal	1.03	1.45%
Total	**0.20**	100.00%

Source: epa.gov and eia.gov for carbon intensities, and statista.com for the energy mix.

been considered in the financial analysis and are therefore corrected by factor CF_p. Thus, to avoid double counting, only the benefit represented by avoided emissions is now examined in detail.

For this purpose, we propose a novel approach. The amount of carbon dioxide (CO_2) emissions avoided by producing 1kWh of electricity with PV coincides with the amount that would have been emitted by the national system to produce the same quantity of electricity. As shown in Table 5, the estimation of this amount depends on the national energy mix and the carbon intensities of the generation technologies used in the country. In 2023, each kWh produced in Spain generated about 0.2 kg of CO_2.[11] However, this value cannot be considered constant over time since Spain has set the objective of achieving net zero emissions in the energy sector by 2050 (Vieira et al., 2021). As the share of non-renewable energy sources will gradually decreases, the amount of CO_2 emissions avoided by the PV plant will also decline. For this reason, we computed carbon intensity over the 25-year time horizon assuming a linear decrease to 0% of non-renewable sources by 2050, while leaving the relative share of renewables unchanged. The monetary evaluation of the quantity of CO_2 avoided is then done by exploiting the market price observed on the EU ETS, as a proxy of the social cost of carbon (Hepburn et al., 2016).[12]

For this purpose, we simulated carbon prices from 2025 onward, based on statistical features observed since 2020, that is, during the most recent period when the market began to show substantial traded volumes. This simulation is based on the assumption that the price of financial instruments can be modelled by stochastic processes such as the geometric Brownian motion (GBM) (Marathe & Ryan, 2005). Indeed, the GBM has several features that make it an ideal candidate for modelling financial variables, such as non-negativity and the possibility to model a deterministic long-term trend, along with a stochastic diffusion (Brătian et al., 2022). More specifically, a variable x_t is said to be drawn by a GBM if it satisfies:

$$dx_t = \mu x_t dt + \sigma x_t dW_t, \tag{4}$$

[11] See https://www.statista.com/statistics/1230694/share-of-electricity-production-by-source-spain/.

[12] Specifically, this system involves the trading of emission permits between companies over a certain size. Hence, the prices of such permits provide a suitable monetary value for the positive externality of reducing emissions, that by its nature does not produce a tangible accounting value (Schauer, 1995).

where μ is the deterministic drift, representing the average deterministic growth rate of carbon prices, σ is the volatility around such trend and dW_t is the increment of a Wiener process (Dixit & Pindyck, 1994). A Wiener process, also called a Brownian motion, is a real-valued continuous-time stochastic process with independent and normally distributed increments (Mikosch, 1998). These characteristics make it suitable for capturing the random component of financial instruments, including carbon prices. The choice to use a GBM is further supported by the fact that the carbon price time series exhibits all its defining characteristics. Specifically, log-returns $r_t = \ln x_{t+1} / \ln x_t$ are (i) not autocorrelated, (ii) normally distributed and (iii) stationary (Biondi & Moretto, 2015). These features have been tested using a Ljung-Box test, a chi-square goodness-of-fit (or, alternatively a Jarque–Bera test) and an augmented Dickey-Fuller, respectively. All these tests confirmed the desired features, not being able to reject the null hypothesis of the absence of autocorrelation and normality, as well as rejecting the null hypothesis of unit root. Carbon price can therefore be said to be drawn by a GBM and its parameters, that is, μ and σ, can be estimated (Ladde & Wu, 2009). The resulting estimate for the trend is $\hat{\mu} = 0.0088$, while the one for the monthly standard deviation is $\hat{\sigma} = 0.0309$. Using these parameters, we ran 1000 simulations of future carbon price trajectories from 2024 to 2049. The average of these simulations is then used to evaluate the externalities. It is worth noting that by the end of the simulation period, the carbon price reaches a thousand euros per metric ton, in line with the relevant scientific literature on this topic (Napp et al., 2019).

An alternative approach to evaluate this externality is offered by the Directorate-General for Climate Action (D CLIMA) of the EC (European Commission, 2022), which provides recommendations concerning the shadow cost of carbon up to 2050. Over the time frame considered in this study, namely 2024–2049, the average value obtained with the GBM-based approach is very close to those suggested by the EC, that is, 437.23 compared to 438.84 euros per metric ton, respectively.[13]

The results of the economic analysis over the 25-year horizon, using a social discount rate of $SDR = 3\%$, show an NSB of approximately 226 thousand euros, about one and a half times the NPV. This yields a benefit-to-cost (B/C) ratio of 4.08, indicating that each euro invested today will generate 4.08 euros in benefits over the next 25 years. Therefore, this finding demonstrates how an already positive financial outcome can be further enhanced by incorporating non-market impacts and externalities into the analysis. In this particular context, the calculation of avoided emissions plays a prominent role, as it leads to an estimated benefit of about 67 thousand euros in current values.

5.2 | Action 2: Water and food efficiency

Financial analysis

The upper part of Table 6 presents the results of the financial analysis for the second action. In this case, the only financial cost is the installation of the sensors, which amounts to 240 thousand euros and does not entail any ongoing maintenance. The change in crop under consideration leads to income changes that must be accounted for in the financial analysis. This shift is driven by the stakeholders' intention to cultivate crop varieties better suited to the new irrigation capabilities enabled by the sensors. Additionally, savings from reduced fertilizer and water use, as well as the corresponding decrease in electricity needed for pumping and distributing water, are also factored

[13] However, the exponential trend shown by the GBM compared with the flatter one proposed by the EC exhibits lower (higher) values at the beginning (end) of the period of interest.

TABLE 6 Details of financial analysis and resulting NPV (above) and those of economic analysis and corresponding NSB (below) of Action 2 (water and food efficiency).

	Total 2024	Year 0 2024	Year 1 2025	Year 2 2026	Year 3 2027	… …	Year 25 2049
Financial analysis							
Sensors installation	−240.00	−240.00	0.00	0.00	0.00	…	0.00
	(−240.00)	(−240.00)	(0.00)	(0.00)	(0.00)	…	(0.00)
Barley yield loss	−155.08	0.00	−9.54	−9.18	−8.82	…	−3.72
	(−248.17)	(0.00)	(−9.93)	(−9.93)	(−9.93)	…	(−9.93)
Wheat yield loss	−71.53	0.00	−4.40	−4.23	−4.07	…	−1.72
	(−114.47)	(0.00)	(−4.58)	(−4.58)	(−4.58)	…	(−4.58)
Poppy yield gain	22.53	0.00	1.39	1.33	1.28	…	0.54
	(36.05)	(0.00)	(1.44)	(1.44)	(1.44)	…	(1.44)
Carrot yield gain	543.52	0.00	33.45	32.17	30.93	…	13.05
	(869.80)	(0.00)	(34.79)	(34.79)	(34.79)	…	(34.79)
Onion yield gain	519.68	0.00	31.99	30.76	29.57	…	12.48
	(831.65)	(0.00)	(33.27)	(33.27)	(33.27)	…	(33.27)
Fertilizer saving	3.65	0.00	0.22	0.22	0.21	…	0.09
	(5.84)	(0.00)	(0.23)	(0.23)	(0.23)	…	(0.23)
Electricity saving	18.66	0.00	1.33	1.16	1.05	…	0.51
	(30.05)	(0.00)	(1.39)	(1.25)	(1.18)	…	(1.36)
NPV (FDR = 4.00%)	**641.43**	−240	**54.44**	**52.22**	**50.15**	**…**	**21.23**
Economic analysis							
Sensors shadow price	−152.26	−152.26	0.00	0.00	0.00	…	0.00
	(−152.26)	(−152.26)	(0.00)	(0.00)	(0.00)	…	(0.00)
Sensors shadow wage	−55.95	−55.95	0.00	0.00	0.00	…	0.00
	(−55.95)	(−55.95)	(0.00)	(0.00)	(0.00)	…	(0.00)
Barley yield loss	−155.57	0.00	−8.67	−8.42	−8.18	…	−4.27
	(−223.35)	(0.00)	(−8.93)	(−8.93)	(−8.93)	…	(−8.93)
Wheat yield loss	−71.76	0.00	−4.00	−3.88	−3.77	…	−1.97
	(−103.03)	(0.00)	(−4.12)	(−4.12)	(−4.12)	…	(−4.12)
Poppy yield gain	22.60	0.00	1.26	1.22	1.19	…	0.62
	(32.45)	(0.00)	(1.30)	(1.30)	(1.30)	…	(1.30)
Carrot yield gain	545.25	0.00	30.40	29.52	28.66	…	14.96
	(782.82)	(0.00)	(31.31)	(31.31)	(31.31)	…	(31.31)
Onion yield gain	521.34	0.00	29.07	28.22	27.40	…	14.30
	(748.48)	(0.00)	(29.94)	(29.94)	(29.94)	…	(29.94)
Fertilizer saving	3.66	0.00	0.20	0.20	0.19	…	0.10
	(5.26)	(0.00)	(0.21)	(0.21)	(0.21)	…	(0.21)
Electricity saving	18.74	0.00	1.21	1.06	0.97	…	0.59
	(27.05)	(0.00)	(1.25)	(1.13)	(1.07)	…	(1.23)
Externality carbon	38.10	0.00	1.24	1.29	1.34	…	0.94
	(57.01)	(0.00)	(1.28)	(1.37)	(1.46)	…	(1.98)

(Continues)

TABLE 6 (Continued)

	Total 2024	Year 0 2024	Year 1 2025	Year 2 2026	Year 3 2027	... ...	Year 25 2049
Externality water	31.24	0.00	1.74	1.69	1.64	...	0.86
	(44.85)	(0.00)	(1.79)	(1.79)	(1.79)	...	(1.79)
NSB (SDR = 3.00%)	**745.38**	−208.21	**52.45**	**50.89**	**49.44**	**...**	**26.13**
|Benefit/cost|	**2.71**						

Note: All values are expressed in thousands of euros. Non-discounted values are shown in brackets.
Abbreviations: FDR, financial discount rate; NPV, net present value; NSB, net social benefit; SDR, social discount rate.

into the analysis. These amounts are estimated considering the change in crop areas together with the average values of water and fertilizer needs, yield and market prices as outlined in Table 2. Although water and fertilizer savings bring about a net positive effect, it is worth noting that this is the result of two separate components. On the one hand, the introduction of soil moisture sensors leads to savings in water and fertilizer. On the other hand, these sensors enable the cultivation of more water- and fertilizer-demanding crops, which can offset part of the initial savings. The valuation of electricity savings is once again based on simulations from Oxford Economics.

Results obtained suggest that this action is also financially viable. Indeed, the NPV over the 25-year horizon, using a 4% FDR, is approximately 641 thousand euros, with a payback time of about 5 years.

Economic analysis

The results of the economic analysis of the second action are shown in the lower part of Table 6. Similarly to the previous case, the CFs are applied to obtain shadow prices and wages, the latter specifically for sensor installation costs only, of the items reported in the financial analysis. To the best of our knowledge, no estimates of the impact of wages in sensor installation are available in the literature. Hence, we use the same share of the first action, that is, 29.5% of the total expenditure.

In the context of this action, two types of externalities can be quantified: (i) avoided emissions and (ii) increased water productivity. While avoided emissions are treated in the same way as described in Section 5.1, increased water productivity is measured by the gross value added) to the water use ratio (D'Odorico et al., 2020; Young & Loomis, 2014). This measure is a useful indicator of the multiplier effect generated in the agricultural industry and related activities, for example, support services and transport, by an investment. For irrigation modernization actions, this effect arises from both increased value added from cultivation and reduced water use (Expósito & Berbel, 2017). While the accuracy of results benefits from local-level multipliers, the best proxy available for this study is an estimate for the Guadalquivir River Basin of 0.12 euros per m^3 (Borrego-Marín & Berbel, 2019). In the absence of more specific data and given the geographical and economic similarities between the two basins, we opted to use this value.

Using an SDR equal to 3% over a 25-year period, the resulting NSB amounts to approximately 745 thousand euros, with an increase of approximately 16% compared to the NPV, resulting in a B/C ratio of 2.71. This finding accounts for the present value of spillovers, generated over the 25-year time frame of interest, by each euro invested in this action. Although to a lesser extent than in the previous case, this result suggests that the second action also delivers considerable social value. Extending the analysis to include environmental and social impacts not only improves the

TABLE 7 Details of economic analysis and corresponding NSB of the two actions combined (WEF nexus).

	Total 2024	Year 0 2024	Year 1 2025	Year 2 2026	Year 3 2027	... ...	Year 25 2049
Economic analysis							
Cost action 1	−73.46	−62.46	−0.61	−0.60	−0.58	...	−0.30
	(−78.25)	(−62.46)	(−0.63)	(−0.63)	(−0.63)	...	(−0.63)
Cost action 2	−435.54	−208.21	−12.67	−12.31	−11.95	...	−6.24
	(−534.59)	(−208.21)	(−13.06)	(−13.06)	(−13.06)	...	(−13.06)
Benefit action 1	299.58	0.00	15.95	14.78	14.42	...	9.09
	(437.48)	(0.00)	(16.43)	(15.68)	(15.76)	...	(19.02)
Benefit action 2	1180.92	0.00	65.13	63.20	61.39	...	32.36
	(1697.91)	(0.00)	(67.08)	(67.05)	(67.08)	...	(67.76)
NSB (SDR = 3.00%)	**971.5**	−270.67	**67.79**	**65.08**	**63.29**	**...**	**34.91**
|Benefit/cost|	**2.91**						

Note: All values are expressed in thousands of euros. Non-discounted values are shown in brackets.
Abbreviations: NSB, net social benefit; SDR, social discount rate; WEF, water–energy–food.

financial outcome but also underscores the project's positive contributions to sustainability and social welfare, aligning its objectives with the broader SDGs.

5.3 | Combined impact on the WEF nexus

In Table 7, we report the result of the economic analysis for both actions described above, to give an encompassing view of the whole project from a WEF nexus perspective. This table summarizes the economic costs and benefits of the two actions, detailed in Tables 4 and 6, showing the resulting combined B/C ratio of 2.91. This result confirms the economic feasibility of the interventions, indicating that each euro invested generates, over the considered time horizon, 2.91 euros of benefits, including positive social and environmental spillovers. Of course, this result lies between the B/C ratios of the two actions considered individually, which produce different outcomes. Specifically, the investment in the PV system generates a B/C ratio of 4.08, while the CSA intervention yields a ratio of 2.71. Even if this result indicates that the first action is financially more cost-effective, from a WEF nexus perspective the combined approach exhibits a higher NSB of the community. The joint analysis enables a more comprehensive assessment of expected impacts and highlights the cumulative benefits generated by the coordinated implementation of both actions, planned and executed by local stakeholders, as part of a unified modernization strategy. Therefore, when the project is evaluated over its entire time horizon and through the integrated perspective of the WEF nexus, the long-term socio-economic and environmental benefits outweigh the short-term costs.

6 | CONCLUSIONS

Over the past decades, water availability and the reliability of water supply have declined due to the effects of climate change, with increasing rainfall variability being a major contributing factor.

This has posed significant challenges in ensuring food security (Hristov et al., 2021). In response, since the 1990s, the Spanish government has initiated a series of investments to modernize water management to enhance the resilience of the agricultural sector and to guarantee the country's food security (Barbero, 2006). These initiatives are part of a broader strategy framed within the WEF nexus, emphasizing water conservation, energy efficiency and food security.

In this study, we assess the impact of modernizing irrigation investments in a district within the DRB through a CBA from a WEF nexus standpoint. We specifically examine two actions aimed at improving resource efficiency and agricultural resilience. The first involves the installation of a PV plant to reduce reliance on the grid, generating both financial and environmental benefits. The second focuses on CSA, particularly the installation of soil moisture sensors to support a transition towards higher value-added crops. For both actions, we demonstrate financial and economic viability, emphasizing their non-financial contributions in terms of externalities. In addition, the joint analysis of the two interventions highlights potential synergies among actions involving different natural resources, reinforcing the value of a WEF nexus perspective.

By demonstrating the long-term feasibility and sustainability of irrigation modernization investments in the DRB, this study offers relevant policy implications for European and Mediterranean countries. On the one hand, our findings can inform assessments of the socio-economic and environmental viability of similar interventions, particularly in contexts where such investment may be contested. Indeed, infrastructure projects often generate tensions and conflicts, as they may impose immediate burdens on local stakeholders, while the benefits may only materialize in the long term (Bazzana et al., 2020). However, our results show that combining investments in PV plants and CSA technologies substantially increases the NSB of the community. This suggests that, when viewed across the full project time horizon and through the lens of the WEF nexus, the long-term socio-economic and environmental gains outweigh the short-term costs. On the other hand, our results can help promote comparable investments in other countries, particularly where supported by European strategies and co-funding mechanisms. For instance, the 'Farm to Fork strategy' seeks to transition the EU agricultural sector towards a more sustainable food production model, emphasizing the need for the efficient use of input resources, such as fertilizer, pesticides and water, as well as the reduction of GHG emissions. Similarly, the new common agricultural policy, in effect since 2023, reinforces agriculture's role in achieving EU environmental and climate objectives (DG AGRI, 2022). Finally, the types of interventions analysed in the DRB align with the broader ambitions of the 'Delivering the European Green Deal' package, which aims to make Europe the first climate-neutral continent by 2050.

This study, however, has several limitations. First, in this analysis, crop yields depend on fertilizer use and irrigation, while other physical, ecological and environmental variables are assumed to be constant over the time frame of interest and unaffected by the two actions. As a result, the potential impacts of climate change on agricultural productivity over the next 25 years are therefore not considered. These impacts include, for example, changes in temperature and precipitation patterns, as well as a higher frequency of extreme weather events. The lack of reliable and localized data and uncertainty surrounding these local effects would make their inclusion in this work challenging. Second, our findings are region-specific, focusing on the DRB, and thus they may not be directly applicable to areas with different climatic, economic, institutional or social characteristics. Indeed, the effectiveness and transferability of the proposed interventions may vary depending on local conditions, such as water availability, land use practices and local governance structures. However, if these differences are properly taken into account, this methodology can also be adapted to other geographical contexts. Third, the study does not incorporate potential political or institutional developments, such as changes in water management policies,

subsidies or broader policy frameworks, which could influence the feasibility and outcomes of the proposed actions. The dynamic nature of water management policies and agricultural support systems could significantly affect the economic and social viability of the interventions over time, particularly in the events of shifts in political priorities. Finally, future studies might consider relaxing some of the standard assumptions used in CBA, as outlined in the EC guidelines (European Commission, 2022), to more explicitly address issues of political legitimacy. In particular, incorporating considerations such as intergenerational equity would be particularly valuable for projects that exploit natural and environmental resources, ensuring that the long-term social and ecological impacts are adequately captured (Sumaila, 2004; Sumaila & Walters, 2005).

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ORCID

Nicola Comincioli https://orcid.org/0000-0002-7177-288X
Cristina El Khoury https://orcid.org/0000-0002-3796-727X
Davide Bazzana https://orcid.org/0000-0002-9561-3699
Demis Legrenzi https://orcid.org/0009-0001-7737-1307
Fernando Nardi https://orcid.org/0000-0002-6562-3159
Daniel A. Segovia-Cardozo https://orcid.org/0000-0002-4110-1823
Sergio Vergalli https://orcid.org/0000-0003-2279-5011
Leonor Rodríguez-Sinobas https://orcid.org/0000-0001-9684-6884

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APPENDIX A: ALTERNATIVE ATTRIBUTIONS OF COSTS AND BENEFITS

The main analysis presented in this study is based on the assumption, motivated in Section 3.2 that only a fraction of total benefits generated by Action 2 has to be attributed to the installation of soil moisture sensors. In addition, since the costs of all works carried out prior to their installation have already been incurred, they are treated as sunk costs and thus excluded from the analysis, as they are not revisable. However, other options for cost and benefits attribution are discussed in this section.

To provide a more comprehensive view of the sensitivity of our results to different assumptions regarding the allocation of costs and benefits, we compute an upper and a lower bound for the B/C ratio, conducting our analysis under the most and least conservative scenarios, respectively. From a conservative perspective, the benefits arising from Action 2, in terms of crop changes, water, energy, and fertilizer savings, could be attributed not solely to the installation of the sensors, but to the entire modernization effort undertaken since 1987. In this scenario, the B/C ratio would be calculated by dividing 100% of the benefits by the shadow cost of sensor installation and all previous expenses. Using the same breakdown between prices and wages as in the main analysis, as well as the same CFs, the present economic value of previous expenses amounts to 3.88 million euros. In this case, the resulting B/C ratio is 2.54. This implies that, even fully incorporating into our analysis all sunk cost incurred in previous decades, thereby reducing the benefit generated per euro spent, this action still remains viable from an economic point of view. Moreover, this result may further strengthen the robustness and credibility of the policy implications derived from the analysis. Conversely, a more shortsighted approach would assign the entirety of the benefits exclusively to the installation of the sensors, de facto neglecting the role of previous developments in achieving these results. In this case, the B/C ratio would instead be computed by comparing 100% of the benefits to the cost of the sensors alone. Following this assumption, the resulting B/C ratio is 4.96. This value can be seen as an upper bound of the B/C ratio, as it implicitly excludes the contribution of prior investments to the generation of observed benefits. However, this is an unrealistic scenario, as it is not reasonable to assume that all benefits can be solely attributed to the soil moisture sensors. Indeed, without the broader set of modernization efforts previously undertaken, the sensors alone would have limited or no effectiveness.

Interestingly, the B/C ratio shows only limited variation, even when significantly altering the attribution of benefits and costs between the baseline scenario and the two alternative scenarios discussed above. Indeed, depending on the scenario, the economic present value of the numerator (denominator) of the B/C ratio ranges between 1.18 and 23.22 million euros (0.44 and 9.16 million euros), while the B/C ratio only varies between 2.54 and 4.96. This inertia is primarily attributable to the fact that the benefits considered are largely driven by the crop change. These benefits represent the gains from the new crops, net of the opportunity costs associated with the crops being replaced. Since these two components are intrinsically linked, any share of benefits attributed to the installation of the sensors is proportionally offset by the corresponding opportunity cost. As a result, variations in the attribution of benefits have only a limited effect on the overall B/C ratio, increasing the reliability of our results.

APPENDIX B: SENSITIVITY ANALYSIS

In order to test the robustness of our main findings, discussed in Section 5, we have conducted a sensitivity analysis for different values of the FDR and the SDR. We replicated our analysis setting both discount rates to higher (h) or lower (l) levels, compared to the baseline case recommended by the EC's guidelines, detailed in Table 3. More specifically, we considered the following scenarios. On the one hand, we set $FDR_h = 6\%$ and $SDR_h = 4\%$, to reflect values commonly used

in scientific literature focusing on projects involving water resources in Southern Europe (Florio, 2006). This scenario is more conservative compared to the main results. Indeed, since the costs of the interventions are mostly concentrated at the beginning of the project, while the benefits materialize over the long term, applying a higher discount rate reduces the relative weight of those future benefits in the B/C ratio calculation. On the other hand, to test the main results under the opposite scenario, we also consider $FDR_l = 2\%$ and $SDR_L = 2\%$. In this case, due to the lower discount rates, long-term benefits are more impactful on the final B/C ratio. Tables B.1 and B.2 focus on Action 1, while Tables B.3 and B.4 present results of Action 2. Finally, Tables B.5 and B.6 present the sensitivity analysis for both actions combined.

The additional results derived from the sensitivity analysis show that, while the NPV and B/C ratio vary with changes in the FDR, the general conclusions remain consistent. Both the PV and soil moisture sensor interventions show positive financial outcomes, with the PV installation still yielding the highest returns. Similar to the sensitivity analysis on FDR, the variations in SDR do not change the overall conclusions, despite affecting both the NSB and the B/C ratio. Indeed, a higher (lower) SDR reduces (increases) the NSB. Even accounting for the variations in the discount rates, the key findings of our analysis are robust. The two actions combined show significant and positive NSB across all tested scenarios. The corresponding B/C ratio supports the economic feasibility of the interventions. Furthermore, the sensitivity analysis highlights that the results are not overly dependent on any single assumption, reinforcing the reliability of the proposed interventions for achieving sustainable water and food efficiency in the DRB.

B1 | Action 1: Energy efficiency

TABLE B1 Results of the sensitivity analysis for Action 1 (Energy efficiency) under high discount rates.

	Total 2024	Year 0 2024	Year 1 2025	Year 2 2026	Year 3 2027	... ...	Year 25 2049
			Financial analysis				
PV installation	−72.00	−72.00	0.00	0.00	0.00	...	0.00
	(−72.00)	(−72.00)	(0.00)	(0.00)	(0.00)	...	(0.00)
PV O&M	−9.20	0.00	−0.68	−0.64	−0.60	...	−0.17
	(−18.00)	(0.00)	(−0.72)	(−0.72)	(−0.72)	...	(−0.72)
AC production	187.99	0.00	14.86	13.12	12.29	...	4.02
	(374.00)	(0.00)	(15.75)	(14.74)	(14.64)	...	(17.25)
NPV (FDR = 6.00%)	**106.79**	−72.00	**14.18**	**12.48**	**11.69**	**...**	**3.85**
Economic analysis							
PV installation shadow cost	−45.68	−45.68	0.00	0.00	0.00	...	0.00
	(−45.68)	(−45.68)	(0.00)	(0.00)	(0.00)	...	(0.00)
PV installation shadow wage	−16.78	−16.78	0.00	0.00	0.00	...	0.00
	(−16.78)	(−16.78)	(0.00)	(0.00)	(0.00)	...	(0.00)
PV O&M shadow cost	−8.01	0.00	−0.49	−0.47	−0.46	...	−0.19
	(−12.82)	(0.00)	(−0.51)	(−0.51)	(−0.51)	...	(−0.51)
PV O&M shadow wage	−1.85	0.00	−0.11	−0.11	−0.11	...	−0.04
	(−2.97)	(0.00)	(−0.12)	(−0.12)	(−0.12)	...	(−0.12)

(Continues)

TABLE B1 (Continued)

	Total 2024	Year 0 2024	Year 1 2025	Year 2 2026	Year 3 2027	… …	Year 25 2049
AC production shadow benefit	207.72	0.00	13.63	12.27	11.71	…	5.82
	(336.60)	(0.00)	(14.17)	(13.27)	(13.17)	…	(15.52)
Externality carbon	59.60	0.00	2.17	2.23	2.30	…	1.31
	(100.88)	(0.00)	(2.26)	(2.42)	(2.59)	…	(3.50)
NSB (SDR = 4.00%)	**194.99**	−62.46	**15.19**	**13.92**	**13.45**	**…**	**6.90**
|Benefit/cost|	**3.70**						

Note: All values are expressed in thousands of euros. Non-discounted values are shown in brackets.
Abbreviations: AC, alternating current; FDR, financial discount rate; NPV, net present value; NSB, net social benefit; O&M, operations and maintenance; PV, photovoltaic; SDR, social discount rate.

B2 | Action 2: Water and food efficiency

TABLE B2 Results of the sensitivity analysis for Action 1 (energy efficiency) under low discount rates.

	Total 2024	Year 0 2024	Year 1 2025	Year 2 2026	Year 3 2027	… …	Year 25 2049
PV Installation	−72.00	−72.00	0.00	0.00	0.00	…	0.00
	(−72.00)	(−72.00)	(0.00)	(0.00)	(0.00)	…	(0.00)
PV O&M	−14.06	0.00	−0.71	−0.69	−0.68	…	−0.44
	(−18.00)	(0.00)	(−0.72)	(−0.72)	(−0.72)	…	(−0.72)
AC Production	290.10	0.00	15.44	14.17	13.79	…	10.51
	(374.00)	(0.00)	(15.75)	(14.74)	(14.64)	…	(17.25)
NPV (FDR = 2.00%)	**204.04**	−72.00	**14.73**	**13.48**	**13.12**	**…**	**10.07**
Economic analysis							
PV installation shadow cost	−45.68	−45.68	0.00	0.00	0.00	…	0.00
	(−45.68)	(−45.68)	(0.00)	(0.00)	(0.00)	…	(0.00)
PV installation shadow wage	−16.78	−16.78	0.00	0.00	0.00	…	0.00
	(−16.78)	(−16.78)	(0.00)	(0.00)	(0.00)	…	(0.00)
PV O&M shadow cost	−10.01	0.00	−0.50	−0.49	−0.48	…	−0.31
	(−12.82)	(0.00)	(−0.51)	(−0.51)	(−0.51)	…	(−0.51)
PV O&M shadow wage	−2.32	0.00	−0.12	−0.11	−0.11	…	−0.07
	(−2.97)	(0.00)	(−0.12)	(−0.12)	(−0.12)	…	(−0.12)
AC Production shadow benefit	261.09	0.00	13.90	12.75	12.41	…	9.46
	(336.60)	(0.00)	(14.17)	(13.27)	(13.17)	…	(15.52)
Externality carbon	76.66	0.00	2.22	2.32	2.44	…	2.13
	(100.88)	(0.00)	(2.26)	(2.42)	(2.59)	…	(3.50)
NSB (SDR=2.00%)	**262.96**	−62.46	**15.49**	**14.47**	**14.26**	**…**	**11.21**
|Benefit/Cost|	**4.52**						

Note: All values are expressed in thousands of euros. Non-discounted values are shown in brackets.
Abbreviations: AC, alternating current; FDR, financial discount rate; NPV, net present value; NSB, net social benefit; O&M, operations and maintenance; PV, photovoltaic; SDR, social discount rate.

B3 | Combined impact on WEF nexus

TABLE B3 Results of the sensitivity analysis for Action 2 (Water and food efficiency) under high discount rates.

	Total 2024	Year 0 2024	Year 1 2025	Year 2 2026	Year 3 2027	… …	Year 25 2049
Financial analysis							
Sensors installation	−240.00	−240.00	0.00	0.00	0.00	…	0.00
	(−240.00)	(−240.00)	(0.00)	(0.00)	(0.00)	…	(0.00)
Barley yield loss	−126.90	0.00	−9.36	−8.83	−8.33	…	−2.31
	(−248.17)	(0.00)	(−9.93)	(−9.93)	(−9.93)	…	(−9.93)
Wheat yield loss	−58.53	0.00	−4.32	−4.08	−3.84	…	−1.07
	(−114.47)	(0.00)	(−4.58)	(−4.58)	(−4.58)	…	(−4.58)
Poppy yield gain	18.43	0.00	1.36	1.28	1.21	…	0.34
	(36.05)	(0.00)	(1.44)	(1.44)	(1.44)	…	(1.44)
Carrot yield gain	444.76	0.00	32.82	30.96	29.21	…	8.11
	(869.80)	(0.00)	(34.79)	(34.79)	(34.79)	…	(34.79)
Onion yield gain	425.25	0.00	31.38	29.61	27.93	…	7.75
	(831.65)	(0.00)	(33.27)	(33.27)	(33.27)	…	(33.27)
Fertilizer saving	2.99	0.00	0.22	0.21	0.20	…	0.05
	(5.84)	(0.00)	(0.23)	(0.23)	(0.23)	…	(0.23)
Electricity saving	15.24	0.00	1.31	1.11	0.99	…	0.32
	(30.05)	(0.00)	(1.39)	(1.25)	(1.18)	…	(1.36)
NPV (FDR = 6.00%)	**481.24**	−240	**53.41**	**50.27**	**47.36**	**…**	**13.19**
Economic analysis							
Sensors shadow price	−152.26	−152.26	0.00	0.00	0.00	…	0.00
	(−152.26)	(−152.26)	(0.00)	(0.00)	(0.00)	…	(0.00)
Sensors shadow wage	−55.95	−55.95	0.00	0.00	0.00	…	0.00
	(−55.95)	(−55.95)	(0.00)	(0.00)	(0.00)	…	(0.00)
Barley yield loss	−139.57	0.00	−8.59	−8.26	−7.94	…	−3.35
	(−223.35)	(0.00)	(−8.93)	(−8.93)	(−8.93)	…	(−8.93)
Wheat yield loss	−64.38	0.00	−3.96	−3.81	−3.66	…	−1.55
	(−103.03)	(0.00)	(−4.12)	(−4.12)	(−4.12)	…	(−4.12)
Poppy yield gain	20.27	0.00	1.25	1.20	1.15	…	0.49
	(32.45)	(0.00)	(1.30)	(1.30)	(1.30)	…	(1.30)
Carrot yield gain	489.17	0.00	30.11	28.95	27.84	…	11.75
	(782.82)	(0.00)	(31.31)	(31.31)	(31.31)	…	(31.31)
Onion yield gain	467.71	0.00	28.79	27.68	26.62	…	11.23
	(748.48)	(0.00)	(29.94)	(29.94)	(29.94)	…	(29.94)

(Continues)

TABLE B3 (Continued)

	Total 2024	Year 0 2024	Year 1 2025	Year 2 2026	Year 3 2027	… …	Year 25 2049
Fertilizer saving	3.29	0.00	0.20	0.19	0.19	…	0.08
	(5.26)	(0.00)	(0.21)	(0.21)	(0.21)	…	(0.21)
Electricity saving	16.79	0.00	1.20	1.04	0.95	…	0.46
	(27.05)	(0.00)	(1.25)	(1.13)	(1.07)	…	(1.23)
Externality carbon	33.68	0.00	1.23	1.26	1.30	…	0.74
	(57.01)	(0.00)	(1.28)	(1.37)	(1.46)	…	(1.98)
Externality water	28.02	0.00	1.72	1.66	1.59	…	0.67
	(44.85)	(0.00)	(1.79)	(1.79)	(1.79)	…	(1.79)
NSB (SDR = 4.00%)	**646.78**	−208.21	**51.95**	**49.92**	**48.03**	**…**	**20.52**
|Benefit/cost|	**2.57**						

Note: All values are expressed in thousands of euros. Non-discounted values are shown in brackets.
Abbreviations: FDR, financial discount rate; NPV, net present value; NSB, net social benefit; SDR, social discount rate.

TABLE B4 Results of the sensitivity analysis for Action 2 (Water and food efficiency) under low discount rates.

	Total 2024	Year 0 2024	Year 1 2025	Year 2 2026	Year 3 2027	… …	Year 25 2049
Financial analysis							
Sensors installation	−240.00	−240.00	0.00	0.00	0.00	…	0.00
	(−240.00)	(−240.00)	(0.00)	(0.00)	(0.00)	…	(0.00)
Barley yield loss	−193.80	0.00	−9.73	−9.54	−9.35	…	−6.05
	(−248.17)	(0.00)	(−9.93)	(−9.93)	(−9.93)	…	(−9.93)
Wheat yield loss	−89.40	0.00	−4.49	−4.40	−4.31	…	−2.79
	(−114.47)	(0.00)	(−4.58)	(−4.58)	(−4.58)	…	(−4.58)
Poppy yield gain	28.15	0.00	1.41	1.39	1.36	…	0.88
	(36.05)	(0.00)	(1.44)	(1.44)	(1.44)	…	(1.44)
Carrot yield gain	679.26	0.00	34.11	33.44	32.79	…	21.21
	(869.80)	(0.00)	(34.79)	(34.79)	(34.79)	…	(34.79)
Onion yield gain	649.47	0.00	32.61	31.97	31.35	…	20.28
	(831.65)	(0.00)	(33.27)	(33.27)	(33.27)	…	(33.27)
Fertilizer saving	4.56	0.00	0.23	0.22	0.22	…	0.14
	(5.84)	(0.00)	(0.23)	(0.23)	(0.23)	…	(0.23)
Electricity saving	23.38	0.00	1.36	1.20	1.12	…	0.83
	(30.05)	(0.00)	(1.39)	(1.25)	(1.18)	…	(1.36)
NPV (FDR = 2.00%)	**861.62**	−240	**55.5**	**54.29**	**53.16**	**…**	**34.49**
Economic analysis							
Sensors shadow price	−152.26	−152.26	0.00	0.00	0.00	…	0.00
	(−152.26)	(−152.26)	(0.00)	(0.00)	(0.00)	…	(0.00)

(Continues)

TABLE B4 (Continued)

	Total 2024	Year 0 2024	Year 1 2025	Year 2 2026	Year 3 2027	… …	Year 25 2049
Sensors shadow wage	−55.95	−55.95	0.00	0.00	0.00	…	0.00
	(−55.95)	(−55.95)	(0.00)	(0.00)	(0.00)	…	(0.00)
Barley yield loss	−174.42	0.00	−8.76	−8.59	−8.42	…	−5.45
	(−223.35)	(0.00)	(−8.93)	(−8.93)	(−8.93)	…	(−8.93)
Wheat yield loss	−80.46	0.00	−4.04	−3.96	−3.88	…	−2.51
	(−103.03)	(0.00)	(−4.12)	(−4.12)	(−4.12)	…	(−4.12)
Poppy yield gain	25.34	0.00	1.27	1.25	1.22	…	0.79
	(32.45)	(0.00)	(1.30)	(1.30)	(1.30)	…	(1.30)
Carrot yield gain	611.33	0.00	30.70	30.10	29.51	…	19.09
	(782.82)	(0.00)	(31.31)	(31.31)	(31.31)	…	(31.31)
Onion yield gain	584.52	0.00	29.35	28.78	28.21	…	18.25
	(748.48)	(0.00)	(29.94)	(29.94)	(29.94)	…	(29.94)
Fertilizer saving	4.11	0.00	0.21	0.20	0.20	…	0.13
	(5.26)	(0.00)	(0.21)	(0.21)	(0.21)	…	(0.21)
Electricity saving	21.04	0.00	1.22	1.08	1.00	…	0.75
	(27.05)	(0.00)	(1.25)	(1.13)	(1.07)	…	(1.23)
Externality carbon	43.33	0.00	1.25	1.31	1.38	…	1.21
	(57.01)	(0.00)	(1.28)	(1.37)	(1.46)	…	(1.98)
Externality water	35.02	0.00	1.76	1.72	1.69	…	1.09
	(44.85)	(0.00)	(1.79)	(1.79)	(1.79)	…	(1.79)
NSB (SDR = 2.00%)	**861.6**	−208.21	**52.96**	**51.9**	**50.91**	**…**	**33.34**
|Benefit/cost|	**2.86**						

Note: All values are expressed in thousands of euros. Non-discounted values are shown in brackets.
Abbreviations: FDR, financial discount rate; NPV, net present value; NSB, net social benefit; SDR, social discount rate.

TABLE B5 Results of the sensitivity analysis for two actions combined under high discount rates.

	Total 2024	Year 0 2024	Year 1 2025	Year 2 2026	Year 3 2027	… …	Year 25 2049
Economic analysis							
Cost action 1	−72.33	−62.46	−0.61	−0.58	−0.56	…	−0.24
	(−78.25)	(−62.46)	(−0.63)	(−0.63)	(−0.63)	…	(−0.63)
Cost action 2	−412.16	−208.21	−12.55	−12.07	−11.61	…	−4.90
	(−534.59)	(−208.21)	(−13.06)	(−13.06)	(−13.06)	…	(−13.06)
Benefit action 1	267.32	0.00	15.80	14.50	14.01	…	7.14
	(437.48)	(0.00)	(16.43)	(15.68)	(15.76)	…	(19.02)
Benefit action 2	1058.94	0.00	64.50	61.99	59.64	…	25.42
	(1697.91)	(0.00)	(67.08)	(67.05)	(67.08)	…	(67.76)
NSB (SDR = 4.00%)	**841.77**	−270.67	**67.14**	**63.83**	**61.48**	**…**	**27.42**
|Benefit/cost|	**2.74**						

Note: All values are expressed in thousands of euros. Non-discounted values are shown in brackets.
Abbreviations: NSB, net social benefit; SDR, social discount rate.

TABLE B6 Results of the sensitivity analysis for two actions combined under low discount rates.

	Total 2024	**Year 0 2024**	**Year 1 2025**	**Year 2 2026**	**Year 3 2027**	**...**	**Year 25 2049**
Economic analysis							
Cost action 1	−74.79	−62.46	−0.62	−0.61	−0.60	...	−0.38
	(−78.25)	(−62.46)	(−0.63)	(−0.63)	(−0.63)	...	(−0.63)
Cost action 2	−463.09	−208.21	−12.80	−12.55	−12.30	...	−7.96
	(−534.59)	(−208.21)	(−13.06)	(−13.06)	(−13.06)	...	(−13.06)
Benefit action 1	337.75	0.00	16.11	15.07	14.85	...	11.59
	(437.48)	(0.00)	(16.43)	(15.68)	(15.76)	...	(19.02)
Benefit action 2	1324.69	0.00	65.76	64.44	63.21	...	41.30
	(1697.91)	(0.00)	(67.08)	(67.05)	(67.08)	...	(67.76)
NSB (SDR = 2.00%)	**1124.56**	−270.67	**68.46**	**66.36**	**65.17**	**...**	**44.55**
|Benefit/Cost|	**3.09**						

Note: All values are expressed in thousands of euros. Non-discounted values are shown in brackets.
Abbreviations: NSB, net social benefit; SDR, social discount rate.