Agricultural Water Management 262 (2022) 107400

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

The social wellbeing of irrigation water. A demand-side integrated valuation in a Mediterranean agroecosystem

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ARTICLE INFO

Handling Editor - J.E. Fernández

Keywords:
Agroecosystem services
Agroecosystem disservices
Human wellbeing
Market valuation
Non-market valuation

ABSTRACT

Irrigation water is a vital input for agricultural production. The supply of irrigation water to crops enhances land productivity and affects the agroecosystem functioning. Agroecosystems co-provide a wide range of agroecosystem services and disservices, which contribute positively and negatively, respectively, to human wellbeing. Therefore, irrigated agroecosystems produce several positive and negative outcomes in relation to society, and agricultural water management is key to the provision of adequate incentives for the enhancement of social wellbeing. In such a context, the aim of this work was to value the contribution of water to the provision of agroecosystem services and disservices, as a way to summarise the contribution of irrigation to social wellbeing. To this end, a demand-side integrated valuation of agroecosystem services and disservices was carried out for both rain-fed and irrigated agriculture in two different agroecosystems of the Region of Murcia (south-eastern Spain), a semi-arid western Mediterranean region characterised by water scarcity. In addition, the intensity of the agricultural water use was considered by distinguishing traditional and highly-intensive irrigated agroecosystems. Almond and lemon, two woody crops, were employed to develop the economic valuation in rain-fed and irrigated agroecosystems, respectively. The assessment of biophysical indicators to quantify the provision of services and disservices and their economic valuation, using market and non-market methods, were used. The results show that the contribution of water to social wellbeing is valued at 9000–12,300 €/ha/year, being greater when the intensive use of agricultural water is promoted. The net economic value of all categories of agroecosystem services and disservices increases when irrigation water is supplied. Notwithstanding, the greatest contribution is due to the increase in provisioning services, mainly food provision in the case of the highly-intensive agroecosystem. Traditional irrigated agroecosystems make a greater contribution to regulating and cultural agroecosystem services. Hence, agricultural water management should focus on increasing the contribution of irrigated agroecosystems to human wellbeing.

1. Introduction

The activity with the greatest use of water, globally, is agricultural irrigation. It accounts for 85% of the total consumptive water use worldwide (WWAP, 2016). The lower availability of water resources expected due to climate change (IPCC, 2019), together with the growing food demand of the human population, will require both increased water productivity and improved water management in the existing agricultural systems (Svendsen and Turral, 2007). Also, irrigated agriculture, integrated with terrestrial and aquatic ecosystems, generates trade-offs with the surrounding ecosystems, such as rivers and lakes, affecting their ecological processes (Gordon et al., 2010). For instance, the use of irrigation water in agriculture may reduce the water resources available for such ecosystems, generating trade-offs between the use of freshwater in agriculture or in surrounding ecosystems (Perni and Martínez-Paz, 2017), especially significant in water-scarce regions. On the other hand, irrigated agriculture with excessive use of fertilisers may be responsible of water bodies eutrophication and thus the degradation

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https://doi.org/10.1016/j.agwat.2021.107400
Received 20 September 2021; Received in revised form 18 November 2021; Accepted 13 December 2021
Available online 29 December 2021
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of aquatic ecosystems, which ends requiring farmers and policy makers actions to be overcome (Alcon et al., 2022). Therefore, water should be managed by the stakeholders in relation to food security, farmers' livelihoods and ecosystems conservation (Boelee, 2013). In this circumstance, dealing with food security and the protection of ecosystems become key tasks to ensure the social wellbeing and should be key elements in the political agenda of agricultural water management, where positive and negative contributions need to be considered. Water resources allocated to irrigation have several purposes and should be managed in a way that provides a wide range of services to society (Falkenmark et al., 2007), considering that markets fail to provide adequate incentives for wellbeing maximisation. This becomes more relevant in areas of water scarcity, such as the Mediterranean countries, where reductions in the allocations of water to agriculture are expected (Molle and Berkoff, 2006).

Irrigation water has been traditionally managed and valued by only considering its contribution to land productivity. However, its contribution could be further, and therefore disentanglement of the value of irrigation water is the first step in the improvement of agricultural water management. Irrigation water is a key input in agricultural systems, mainly because of its capacity to increase land productivity, but also for food security, rural livelihoods and, above all, the support of agroecosystems health (WWAP, 2021). Despite its crucial importance, irrigation water remains undervalued, not only by farmers, who do not always pay for its real value, but also by decision makers, who often do not take properly informed decisions. Water scarcity makes irrigation water more valuable, meaning that alternative, and even competing, uses require water management that is guided by efficient and sustainable decisions (Sultana and Loftus, 2020). The economic value of natural resources, either goods or services, measures their contribution to human wellbeing (Freeman et al., 2003). Hence, the challenge of valuing irrigation water is straightforward: it should be valued not only considering its contribution to land productivity, but also its overall contribution to human wellbeing.

Agroecosystems are anthropised ecosystems that generate a wide set of ecosystem services as results of the ecosystem functioning and human interaction (Fischer and Eastwood, 2016). Human interference, mainly through agricultural practices, can greatly influence the agroecosystem impact on human wellbeing (Dale and Polasky, 2007), by producing both agroecosystem services (AES) and agroecosystem disservices (AEDS) that impact, positive or negatively, respectively, human wellbeing (Power, 2010; Shackleton et al., 2016). The provision of AES and AEDS depends on the agroecosystem functioning as well as on the state of health of the agroecosystem and the biodiversity, both of which determine the agroecosysteḿs capacity (Zabala et al., 2021a). Within such anthropised ecosystems, water, as a core resource for life, is key to agroecosystem functioning and capacity, and so affects the provision of AES and AEDS flows. Water affects the innate agroecosystem functioning. Supplying water for irrigation interferes with the agroecosystem state, biodiversity and functioning, consequently contributing to the provision of AES and AEDS (Boelee, 2013). However, agricultural water not only contributes to AES and AEDS flows, but also could be directly responsible for the provision of AEDS itself. For instance, the use of agricultural water for irrigation decreases the availability of water for other uses and ecosystems, therefore providing AEDS, mainly when semi-arid and arid environments are involved. The greater the use of water for agricultural purposes the lower its availability for alternative uses, especially environmental ones, and thus the greater the AEDS.

The ecosystem service approach provides, therefore, a framework for the assessment and valuation of the contribution of water to AES and AEDS; namely, the way in which agricultural water contributes to human wellbeing. The supplying of water to agriculture will contribute to agroecosystem functioning and capacity, therefore impacting the provision of AES and AEDS, which are finally translated into contributions to human wellbeing (Gordon et al., 2010). In addition, AES and AEDS represent benefits and costs, respectively, within the socioeconomic system, as a consequence of the economic valuation of their contribution to human wellbeing made using market and non-market valuation methods (Zabala et al., 2021a). The valuation of AES and AEDS represents a way to summarise in monetary units the contribution of AES and AEDS to human wellbeing and, thus, also the contribution of agricultural water to human wellbeing. For valuation purposes, Zabala et al. (2021a) established a comprehensive framework to accommodate the agroecosystems within the existing ecosystem services classifications, namely MEA (2005), TEEB (2010) and CICES (Haines-Young and Potschin, 2018). Also, Zabala et al. (2021a) identified the main AES and AEDS in semi-arid western Mediterranean agroecosystems and indicated that policies intended to maximise wellbeing should consider irrigation water.

In the literature, several methods for the estimation of the economic value of irrigation water have been described (Young, 2005). In mono-criteria and multi-criteria analysis using mathematical programming to consider the value of irrigation water, the criterion of maximising yields or maximising farmers' utility, respectively, is applied. Thus, a profit maximising approach is applied for the value of irrigation water in mono-criteria programming (e.g. Chaudhry and Young, 1989), while multi-criteria analysis seeks to understand farmers' behaviour by maximising a utility function representing their preferences (e.g. Gómez-Limón and Berbel, 2000; Berbel et al., 2009). The production function method has also been applied to estimate the value of irrigation water (e.g. Mesa-Jurado et al., 2010; Bierkens et al., 2019). This is based on the estimation of the production function of irrigated crops, the economic value of the marginal productivity of water being ceteris paribus the shadow price of the irrigation water. The residual valuation method assumes that a profit-maximising farm will use irrigation water up to the level where the net revenue gained from an additional unit of water equals the marginal cost of the irrigation water (Lange, 2006). In practice, the residual valuation method is based on the assumption that competitive markets exist for all the production factors except water; namely, the marginal cost of such factors is known, and therefore the value of irrigation water is just the net returns to water - that is, the total value of crop production after subtracting the value of non-water input factors. This method has been developed, among others, by Berbel et al. (2011) and Ziolkowska (2015). Despite being less usual, stated preference methods have also been applied to estimate the value of irrigation water, using either contingent valuation (e.g. Colino and Martínez-Paz, 2007; Martínez-Paz and Perni, 2011) or a choice experiment (Rigby et al., 2010; Barreiro-Hurle et al., 2018; Alcon et al., 2019). In recent years, the focus has been on estimating the economic value of irrigation water by comparing the market benefits in irrigated and non-irrigated farms (e.g. D'Odorico et al., 2020). However, in spite of the great number of works encompassing the economic value of irrigation water, all of them share the same approach. They focus on the contribution of water to the farm benefits, centred only on market valuation, but not those affecting the whole society. Indeed, these works assume irrigation water to be just another resource, a factor of production that only affects, and is affected by, farmers' decisions. However, as mentioned above, the impact of irrigation water goes beyond the farm gate, ultimately influencing human wellbeing.

In such a context, the aim of this study was to value the contribution of irrigation water to human wellbeing, by determining the value of the provision of AES and AEDS in irrigated agroecosystems. To this end, the contribution of agricultural water to the value of AES and AEDS was estimated by comparing the social demand-side and integrated market and non-market values of irrigated crops with the respective values of rain-fed crops. The Region of Murcia (south-eastern Spain), a semi-arid western Mediterranean region characterised by an important irrigated agriculture sector and by water scarcity, was used as the case study. The wellbeing impact of irrigation water allocations was explored, to inform normative policies and to design economic policy instruments.

The novelty of this paper lies in the valuation of irrigation water according to its contribution to human wellbeing through the ecosystem service approach. The results are expected to provide a better insight into the impacts of irrigation water from a comprehensive point of view. The use of a demand-side approach for the valuation methods adds to the novelty of the results. In addition, the paper also contributes to the ongoing research into the integrated economic valuation of AES and AEDS, including most of the AES and AEDS identified by Zabala et al. (2021a) for semi-arid western Mediterranean agroecosystems.

2. The demand-side approach and the integration of AES and AEDS

The cornerstones of the present work are (1) the use of a demand-side approach for the economic valuation of the contribution of water to wellbeing and (2) the integrated valuation of AES and AEDS. The use of a demand-side approach allows us to make human wellbeing the focus of the economic valuation. All the valuation methods employed are centred on the social demand, either actual -revealed by markets- or inferred -revealed by means of stated preference methods-. This ultimately requires the integration of market and non-market valuation methods to estimate the values of AES and AEDS. The market price method seems appropriate to estimate the values of services that are tradeable on well-functioning markets (Bateman et al., 2014), such as markets for food and agricultural inputs. Meanwhile, the non-market benefits and costs should be estimated by focusing on the demand side, considering the human wellbeing gain resulting from the change in AES and AEDS by eliciting individuals' willingness to pay for this change (Birol et al., 2006). Only in this way does human wellbeing become the foundation of the economic valuation. However, examples of such kinds of studies are scarce in the literature. Some papers combine demand and supply methods to estimate the values of AES, ignoring the fact that supply-side methods cannot be used to compare costs and benefits, being useful and illustrative only in specific circumstances (Alcon et al., 2010). Examples of the use of supply-side non-market valuation methods to value some AES, combined with demand-side methods to value other AES, can be found in Hardaker et al. (2020), where the replacement cost method was used to value carbon sequestration or local flood risks, and in Sandhu et al. (2020) and Chang et al. (2011), where this method was employed to value erosion services.

Despite the efforts made to show the relevance of including both AES and AEDS in agroecosystem valuation (Power, 2010, Shackleton et al., 2016; Blanco et al., 2019) and their relevance to policy makers (Sandhu et al., 2019), previous studies have dealt with a limited set of AES and AEDS, overlooking some of the overall impacts that agroecosystems have on human wellbeing. For instance, Chang et al. (2011), using greenhouse vegetable cultivation in China as a case study, considered yield, CO_2 fixation, soil retention, soil fertility and water saving as AES and soil salinization and N_2O emissions as AEDS to show that, even when considering the value of AEDS, the use of greenhouses for vegetable production yields net economic benefits. In Wales, Hardaker et al. (2020) compared the net economic benefits of agriculture and forestry land uses. They concluded that, even considering that most of the disservices were derived from agriculture, the economic value of the benefits from agriculture was higher than that of those from forestry. To this end, they estimated the economic value of crop production, water supply for consumptive use, carbon sequestration and employment as AES, and potable water quality reduction and greenhouse gas emissions as AEDS. In Minnesota, Sandhu et al. (2020) compared the net benefits of producing genetically modified corn with those of organically produced corn by using the TEEBAgriFood framework (TEEB, 2018). For the AES, these authors considered only the corn grain yield, while services associated with water (groundwater pollution), soil (erosion) and air quality (CO_2 and N_2O emissions), together with health costs, were used as AEDS. Recently, (Zhen et al., 2021), by combining both supply and demand valuation methods, showed that the value of AEDS in conventional greenhouse production in China clearly surpasses the value of AEDS for organic production. These are, to our knowledge, the only studies that have dealt with the integration of AES and AEDS to date. Therefore, the present work is expected to contribute to the increasing literature regarding the integrated valuation of AES and AEDS, accounting all the significant contributions of agroecosystems to wellbeing in semi-arid western Mediterranean irrigated agriculture.

Consideration of the contribution of irrigation water to human wellbeing when determining its value will better guide water decision makers in their commitment to agricultural water management, since then not only the contribution of irrigation water in relation to farmers but also for the entire society will be included. In addition, the integrated valuation of agroecosystems, including both market and non-market values of AES and AEDS, informs policy makers in the implementation of normative and economic policy tools (Zhen et al., 2021) intended to produce sustainable and resilient agroecosystems (Sandhu et al., 2019). Water policies in Europe, within the Water Framework Directive (WFD) [Directive 2000/60/EC] context, would be better informed in relation to the selection of specific measures to achieve the good ecological status of water bodies. Thus, investment or delegation decisions would be better justified by including benefits and beneficiaries from water ecosystem services that had not been taken into account (Grizzetti et al., 2016). Also, the adoption of economic tools to achieve the full water services cost recovery principle would be better justified (Alcon et al., 2012). Agricultural policies, such as the Common Agricultural Policy (CAP), would benefit from the integrated valuation of agroecosystems, with regard to the adjustment of regional payments according to their social benefits and the design of potential eco-schemes to be included in the future CAP, to reach the Green Deal targets. Therefore, this work is expected to be useful for the making of decisions about agricultural water management, based on the specific characteristics of the agroecosystem, and for the adoption of agricultural policies that maximise the social wellbeing that the agroecosystem imparts to society, by showing the total cost of the products, including the environmental and social costs. It will also support water policies in the establishment of normative criteria and the design of economic instruments in water-scarce areas by assessing environmental sustainability and providing a reference for compensation.

3. Methodology

The methodology applied to value the contribution of irrigation water to wellbeing combines biophysical indicators and economic valuation methods and is applied to rain-fed and irrigated agroecosystems. It is based on the notion that irrigation water increases the flow, and thereby the value, of AES and AEDS in irrigated agroecosystems with respect to rain-fed agroecosystems. Therefore, the contribution of irrigation water to human wellbeing is represented by the increase in economic value from rain-fed to irrigated agroecosystems. The analytical framework followed is presented in Fig. 1.

3.1. Case study description

The Region of Murcia, within the Segura River Basin (south-eastern Spain), is used as the case study. In order to deal with the main agroecosystems, two specific areas, namely Ricote and Campo de Cartagena, were selected in order to include rain-fed agroecosystems combined with both traditional and highly-intensive irrigated agroecosystems. Thus, four main sub-systems were assessed and valued: (1) traditional rain-fed; (2) traditional irrigated; (3) highly-intensive rain-fed; (4) highly-intensive irrigated. Fig. 2 shows the case study areas, which combined irrigated areas with rain-fed agroecosystems, representative of water-scarce areas where the availability of irrigation water is limited. The village of Ricote, within the Ricote Valley in the Segura River Basin, is an area that has been irrigated since the 10th–13th centuries AD (Balbo et al., 2020). The county of Campo de Cartagena is an agricultural area, consolidated in the 1980 s, that combines highly-intensive citrus and vegetables crops with rain-fed crops. Both

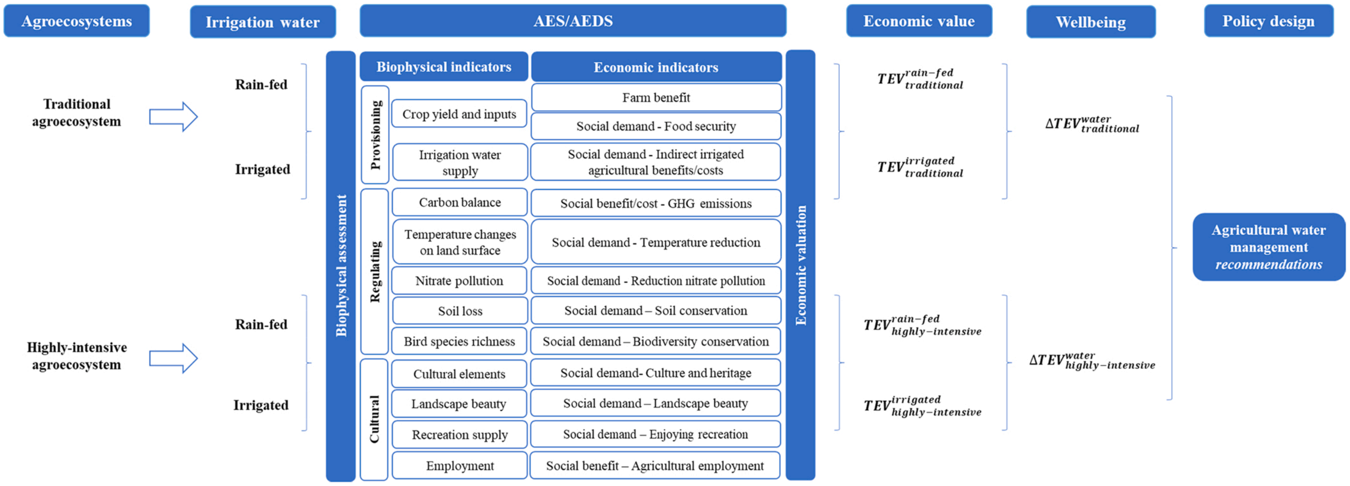

Fig. 1. Analytical framework.

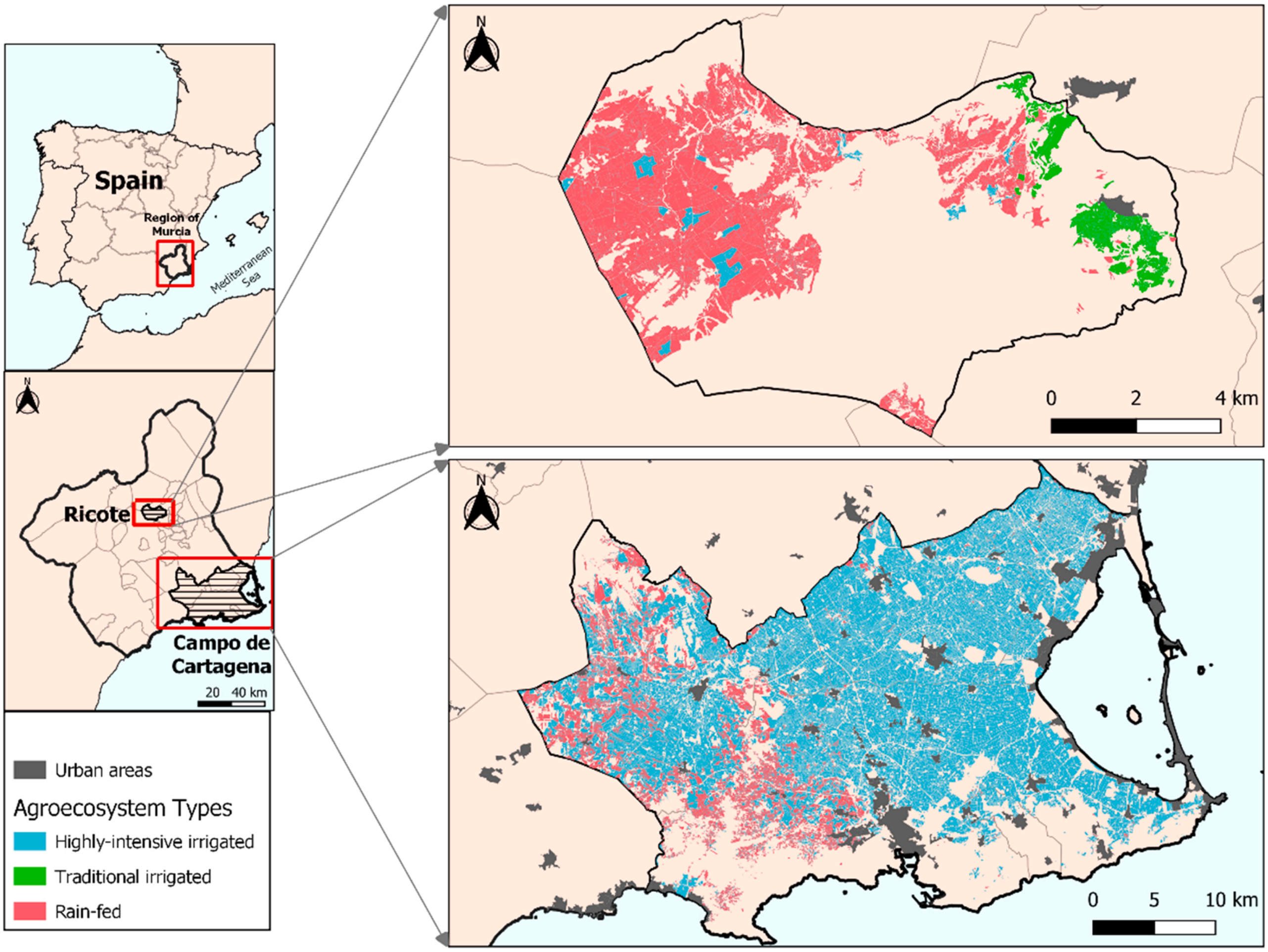

Fig. 2. Case study area.

these agroecosystems are characterised by the historical use of irrigation water and, currently, intensive management.

The Ricote Valley agroecosystem combines areas of rain-fed crops, mainly occupied by almond orchards (76.6%), with an irrigated area historically used for subsistence by the inhabitants and transformed into lemon orchards in 1962 (Puy, 2014). Currently, 79.0% of the irrigated area is covered by lemon orchards, as shown in Table 1. The main irrigation water source, the Segura River, is supplemented with the use of perennial springs. Uncertain and variable water allocations have driven the modernisation of the irrigation infrastructure over recent decades. A collective drip irrigation system is maintained by the 620 irrigators that, together, own a highly fragmented area (Heider et al., 2018). Both rain-fed and irrigated crops are mainly grown on terraces flanked by mountainous Mediterranean forests (Puy and Balbo, 2013).

Table 1
Crop distribution in agroecosystems of Ricote and Campo de Cartagena. Source: CARM (2021a).

	Ricote *Traditional agroecosystem*				Campo de Cartagena *Highly-intensive agroecosystem*			
	Rain-fed		Irrigated		Rain-fed		Irrigated	
	ha	%	ha	%	ha	%	ha	%
Woody crops	1143	98.70	265	96.01	5267	85.48	9493	29.92
Lemon	0	–	218	78.99	0	–	3619	11.40
Almond	887	76.60	16	5.80	4344	70.50	892	2.81
Herbaceous crops	15	1.30	11	3.99	895	14.52	22,240	70.08
Horticultural crops	0	–	3	1.09	0	–	18,215	57.40
Cultivated area[a]	1158	100.00	276	100.00	6162	100.00	31,733	100.00

[a] Excluding fallow land.

The typical agricultural landscapes, with remains of traditional water systems (e.g. waterwheels and traditional irrigation ditches) along with the maintenance of traditional agricultural practices and elements (e.g. terraces and stone walls) and intergenerational ecological knowledge, represent a cultural and landscape heritage with a growing touristic and recreation interest (Heider et al., 2021). The agri-environmental benefits comprise local climate regulation, soil maintenance and biodiversity.

The Campo de Cartagena county covers 48,972 ha of agricultural lands mainly occupied by irrigated crops. The main woody irrigated crop is lemon, with 3619 ha; together with other citrus species and horticultural crops, it represents the main irrigated area in the Region. Irrigated crops are mixed with rain-fed orchards, almond, with 4344 ha, being the most representative of these agroecosystems. The irrigated area is mainly within the Campo de Cartagena Irrigation Community domain. The main water source is the transfer from the Tajo River to the Segura River Basin, through the Tajo-Segura aqueduct; this is combined with other sources, such as surface, groundwater, desalinated and reclaimed water (Martínez-Paz et al., 2018). Water is distributed among the farmers by a pressurised remote-control distribution network. Nearly all the plots, owned by more than 9500 farmers, are equipped with drip irrigation technology (Alcon et al., 2017). This irrigated area dates from the 17th century, when groundwater was extracted by windmills, infrastructures that are included in the heritage red list. Agri-environmental challenges in this area relate to water conservation, groundwater pollution and biodiversity.

Given the crop distribution in both areas and in order to integrate their similarities, the present study is centred on woody crops: lemon orchards in irrigated sub-systems and almond orchards in rain-fed ones. These two crops were chosen due to their importance and representativeness for both agroecosystems. Therefore, it is assumed that almond orchards substitute for lemon orchards in the absence of irrigation water, given that almond is the main rain-fed crop in all the case study area.

3.2. Biophysical assessment

Several approaches are used to assess biophysical indicators for AES and AEDS. Some authors have employed indicators that combine ecological and economic aspects within the spatial dimension (Bagstad et al., 2013) while others have used proxies of the AES directly related with the ecosystem, as a flexible approach to measure AES (Layke et al., 2012; Grizzetti et al., 2016) and their useful capacity for spatial accounting. Provisioning, regulating and cultural categories of services and disservices were used to classify AES and AEDS and their related indicators. Our approach also includes supporting (MEA, 2005) and habitat (TEEB, 2010) services in the regulating category, only if they do not imply a double-accounting bias (see Zabala et al., 2021a). This is the case of the agroecosystem contribution to biodiversity. Thus, in the present work, suitable indicators for AES and AEDS were selected and assessed to link the biophysical assessment with the economic valuation. All the indicators refer to 2019, which was used as the base year for the assessment. The definitions of the indicators employed for the semi-arid Mediterranean agroecosystems are shown in Table 2.

Provisioning services encompass food provision and the agricultural impact on fresh water resources; that is, irrigation water. Both indicators were estimated by using secondary sources. Interviews with farmers were carried out to identify the technical farm characteristics for each agricultural sub-system (10 interviews per sub-system).

Food provision is directly associated with crop yield, being measured as the crop yield in kg per hectare and year. Among the provisioning AEDS, the water supply for irrigation was also included in the biophysical assessment, given the competition for water resources among alternative uses in semi-arid regions with water scarcity issues, such as the case study area (Perni and Martínez-Paz, 2017; Zabala et al., 2019). The indicator employed was the amount of water supplied for irrigation in each sub-system, measured in cubic metres per hectare and year, following Zabala et al. (2021a), (2021b).

Biophysical indicators to account regulating AES and AEDS were obtained by using quantifiable proxy indicators in the study area, whose data came from secondary sources and scientific literature. Emission of contaminants to the atmosphere (considered one of the AEDS) and global climate regulation (one of the AES) are measured generally on the basis of the CO_2 balance, which combines the CO_2 emissions from input use, measured by the life cycle assessment indicators (Martin-Gorriz et al., 2020a, 2020b), and CO_2 sequestration, measured as the crop carbon sequestration along its lifespan, as estimated by Carvajal et al. (2010) for the analysed crops. At the local level, irrigated crops can regulate the climate by modifying the surface temperature. In the case study area, Albaladejo-García et al. (2020) found that irrigated citrus crops can reduce the temperature by up to 2°C.

Irrigation water, besides its role as one of the competing provisioning AEDS, also acts as one of the regulating AEDS due to its purification and waste treatment capacity. In many water-scarce areas, where intensive agricultural systems predominate, the purification role of water is inverted, agricultural water being a source of diffuse pollution. Thus, the nitrate concentration in the aquifers in the case study area is used as a proxy indicator for water purification and waste treatment AEDS.

Soil maintenance in agriculture is related extremely closely to the agricultural practices. Thus, agroecosystems can provide AES or AEDS, according to the agricultural practices implemented by the farmers. In the study area, where soils are poor in organic matter and rainfall is scarce, agriculture provides AEDS associated with the loss of soil due to wind or precipitation if soil conservation practices are not applied (Boix-Fayos et al., 2005). In this work, soil loss was measured using the soil erosion national inventory, based on the RUSLE model (MITECO, 2021), as a proxy for the soil maintenance service.

In agroecosystems, biodiversity allows the regulation of the physical, chemical and biological conditions, as well as pest and disease control. Indeed, biodiversity was identified by experts as the most relevant of the AES in the case study area (Zabala et al., 2021a). The Margalef bird species richness index (Magurran, 2004) was estimated for each sub-system as a biodiversity proxy, using the eBird geo-located database in the study area (eBird, 2021).

The non-material nature of cultural AES means that the selection of measurement indicators for cultural AES is always challenging. According to the characteristics of the case study area and the information available, obtained from interviews with farmers, field visits and geophysical data, the indicators included in Table 2 were used. The culture, art and design AES were measured by using four indicators: presence of terraces, dry stone walls, historic elements and cultural identity. The presence of such cultural and historical elements within agroecosystems landscapes is related to the agricultural and water management and is also considered a sign of place identity. The aesthetic value contributing to the AES, defined as the scenic landscape beauty, was measured as the landscape heterogeneity, considering the agricultural land covered by crops other than the one analysed for each sub-system. This indicator was obtained using the Spanish land parcel identification system (SIGPAC, 2021), where the different agricultural land covers are identified. Opportunities for recreation and tourism AES were measured as the chance of enjoying such kinds of activities within the agroecosystems, using as an indicator the final value of the outdoor recreation available in ARIES (Artificial Intelligence for Ecosystem Services), which follows the Paracchini et al. (2014) proposal for assessing the potential for outdoor recreation across the European Union. The cognitive development and good living AES were identified as the employment generated by the agroecosystems (Laterra et al., 2019), measured in annual work units (AWU) per hectare and year.

3.3. Economic valuation

The total economic value (TEV) of the agroecosystems was calculated by aggregating the economic value of all AES and AEDS identified for the four sub-systems. Based on biophysical indicators, both market and non-market values were estimated for the AES and AEDS and these were aggregated (Sandhu et al., 2008):

$$TEV_{total_i} = TEV_{market_i} + TEV_{non-market_i} = TEV_{provisioning_i} + TEV_{regulating_i} + TEV_{cultural_i} \tag{1}$$

Where the total economic value (TEV_{total_i}) represents the economic value of the AES and AEDS provided by each of the i sub-systems assessed. TEV_{total_i} can be decomposed according to the market (TEV_{market_i}) and non-market ($TEV_{non-market_i}$) nature of the economic value, as well as by considering the contributions of the different categories of AES and AEDS: provisioning ($TEV_{provisioning_i}$), regulating ($TEV_{regulating_i}$) and cultural ($TEV_{cultural_i}$).

The economic value of the AES and AEDS was estimated per hectare and year, by combining the corresponding biophysical indicator (i.e. tonnes CO_{2eq}/ha year) and its unit economic value (e.g. €/t CO_{2eq} in terms of avoided social costs for carbon sequestration). Therefore, the total economic value of the AES and AEDS provided by each sub-system i was calculated as follows (Hardaker et al., 2020):

$$TEV_{total_i} = \sum_{n=1}^{N} EV_{n_i} = \sum\nolimits_{n=1}^{N} S_{n_i} P_{n_i} \tag{2}$$

Where EV_{n_i} encompasses the economic value of each n AES and AEDS, S_{n_i} represents a n of the AES and AEDS supplied by a specific agricultural sub-system i, measured in biophysical units, and P_{n_i} is the marginal value estimated for the specific AES or AEDS. The AES and AEDS show positive and negative marginal values, respectively. As Eq. (2) reveals, a linear marginal value is assumed for AES and AEDS. Notwithstanding, this is not always the rule (Watson et al., 2021). Indeed, as Zabala et al. (2021b) stated for this kind of agroecosystem, the marginal utility decreases for some of the AES and AEDS, specifically food provision, irrigation water, and water purification and waste treatment. Therefore, we used the consumer surplus instead for the economic value of such AES and AEDS, following Zabala et al. (2021b).

The use of a demand-side approach for non-market valuation methods allowed us to consider social preferences, and thereby the use and non-use values within the total economic value estimations, thus obtaining the difference in wellbeing between the irrigated and rain-fed sub-systems. Thus, the contribution of irrigation water to the value of irrigated agroecosystems, that is, the wellbeing gain of irrigation water, can be estimated as follows:

$$\Delta TEV_{total_i}^{water} = TEV_{total_i}^{irrigated} - TEV_{total_i}^{rain-fed} \tag{3}$$

Where $\Delta TEV_{total_i}^{water}$ represents the contribution of irrigation water to the total economic value of the agroecosystems, and $TEV_{total_i}^{irrigated}$ and $TEV_{total_i}^{rain-fed}$ are the total economic value of the AES and AEDS provided by irrigated and rain-fed agroecosystems, respectively. In addition, the contribution of irrigation water can be decomposed into the contributions from market ($\Delta TEV_{market_i}^{water}$) and non-market ($\Delta TEV_{non-market_i}^{water}$) sources of economic value and those from the provisioning ($\Delta TEV_{provisioning_i}^{water}$), regulating ($\Delta TEV_{regulating_i}^{water}$) and cultural ($\Delta TEV_{cultural_i}^{water}$) AES and AEDS, as follows:

$$\Delta TEV_{total_i}^{water} = \Delta TEV_{market_i}^{water} + \Delta TEV_{non-market_i}^{water} = \Delta TEV_{provisioning_i}^{water} + \Delta TEV_{regulating_i}^{water} + \Delta TEV_{cultural_i}^{water} \tag{4}$$

The contribution of irrigation water to the total economic value of the irrigated agroecosystems allows determination of the total economic productivity (TEP_{water_i}) and the total economic value of irrigation water (V_{water_i}), both measured in €/m^3 (D'Odorico et al., 2020):

$$TEP_{water_i} = \frac{TEV_{total_i}^{irrigated}}{Irrigation \quad water} \tag{5}$$

$$V_{water_i} = \frac{\Delta TEV_{total_i}^{water}}{Irrigation \quad water} \tag{6}$$

Hence, these values represent the average wellbeing impact that

Table 2
AES and AEDS definitions and biophysical indicators.

	AES / AEDS	Definition (Indicator)	Units	Source
Provisioning services	Food (AES)	Yield and associated production inputs	kg/ha/year	Own elaboration based on farmers interviews
	Irrigation water (AES/AEDS)	Irrigation water supplied to the sub-system	m^3/ha/year	Own elaboration based on farmers interviews
Regulating services	Emissions of contaminants to the atmosphere (AEDS) Global climate regulation (AES)	Net balance between CO_{2eq} sequestration and emission	t CO_{2eq}/ha/year	Own elaboration. Emission estimated on the basis of Martin-Gorriz et al. (2020a, 2020b) indicators. Sequestration estimated on the basis of Carvajal et al. (2010)
	Local climate regulation (AES)	Temperature changes on the land surface	°C	Albaladejo-García et al. (2020)
	Water purification and waste treatment (AEDS)	Nitrate concentration in aquifers	mg/L NO_3^-	CHS (2021)
	Soil maintenance (AES/AEDS)	Loss of soil due to wind or precipitation	t soil/ha/year	Own elaboration based on RUSLE model (MITECO, 2021)
	Biodiversity (AES/AEDS)	Bird species richness with respect to potential	%	Margalef Index (Magurran, 2004), using eBird database (eeBird, 2021)
Cultural services	Culture, art and design (AES)	Presence of cultural elements linked to agriculture. Four indicators: presence of terraces, dry stone walls, historic elements and cultural identity	Yes/no	Own elaboration based on farmers interviews and field visits
	Aesthetic values (AES)	Scenic landscape beauty. Landscape heterogeneity measured as the percentage of agricultural land covered by crops other than the one analysed in the sub-system	%	SIGPAC (2021)
	Opportunities for recreation and tourism (AES)	Chance of enjoying activities in agroecosystems. Theoretical recreation supply based on Euclidean distance to protected areas, water bodies and sites of touristic relevance	0–1 Index	Paracchini et al. (2014), obtained from ARIES (ARtificial Intelligence for Ecosystem Services) (Villa et al., 2014)
	Cognitive development and good living (AES)	AWU related to agroecosystems management	AWU/ha/year	Own elaboration based on farmers interviews

irrigation water provides.

Table 3 shows the market and non-market valuation methods followed to estimate the economic values of the AES and AEDS, together with the economic indicators and their sources. They were estimated based on the values of the biophysical indicators assessed in Table 2. The methods employed to value the AES and AEDS included direct on-demand estimations in the study area, based on the choice experiment carried out by Zabala et al. (2021b), and indirect estimations obtained outside the study area but transferred, using benefit transfer, to the case study. For the benefit transfer, economic values obtained from other regions were normalised in terms of purchasing power parity (World Bank, 2021), and the prices were normalised to 2019, the reference year for non-market valuation in Zabala et al. (2021b), by using the standard consumer price index (INE, 2021). For standardisation purposes, different valuation units were converted to the economic value per hectare, by sub-system.

The market price method provides the economic value of the AES flows traded in markets. In consequence, this method was applied here for food provision; specifically, this was valued through farm benefits, which consider the revenues from the value of the crop yield, once the variable and fixed costs have been subtracted. Irrigation water is thereby included as a variable cost in the estimation of farm benefits, using the price paid by farmers for water in each agroecosystem. However, given the water scarcity in the case study area, irrigation water is also considered to be one of the AEDS due to the existence of competing uses (Zabala et al., 2019) and the social demand for water-allocation solutions (Perni and Martínez-Paz, 2017). Therefore, the use of water for irrigation could be seen as having a negative impact on human wellbeing if it reduces significantly the water resources available for alternative uses. The agricultural impact on wellbeing due to the use of irrigation water will depend on the amount of irrigation water employed, in accordance with a non-linear utility function (Zabala et al., 2021b). Food security is also understood as a positive contribution of agroecosystems to human wellbeing. Hence, both water supply and food security services were valued in a non-market way, following a choice experiment implemented in the case study area (Zabala et al., 2021b).

The value of the regulating services was measured by means of non-market valuation methods. A positive (negative) carbon balance implies social benefits (costs) in terms of the avoided (actual) social costs that the net CO_{2eq} sequestration (emission) supposes. The economic value associated with these AES -or AEDS, depending on the sign of the carbon balance- has a marked global character, whose benefits (costs) expand beyond the limits of the local and regional agroecosystems. However, the rest of the regulating AES and AEDS are confined to the regional limits, and their social demand was estimated by using the choice experiment method in the case study area. Only the value for the soil erosion was transferred; from a study of woody crops in Andalusia (southern Spain), given the proximity of the two regions and the similarity of the problem in them.

The cultural value of the traditional and highly-intensive agroecosystems was estimated by using a demand-side approach with non-market methods. The presence and maintenance of cultural and historical elements associated with irrigation and agriculture was valued through benefit transfer from stated preference methods applied in other agroecosystems similar to those of the case study area. These were the Adra and Nacimiento watershed (south-eastern Spain), where almond orchards and terraces were valued (García-Llorente et al., 2012), the Peninsula of Sorrento (southern Italy), where the presence of elements of heritage was valued (Tagliafierro et al., 2013), and the Huerta of Murcia (south-eastern Spain), where the value of the cultural and historical identity associated with traditional irrigated lands was estimated (Martínez-Paz et al., 2019). Arriaza et al. (2008) showed that agricultural woody landscapes with a greater variety of vegetation are more valuable. Their approach and economic values were then transferred from Andalusia (southern Spain) to estimate the economic value

Table 3
AES and AEDS economic valuation.

	AES / AEDS	Economic indicators	Units	Valuation method	Source
Provisioning services	Food (AES)	Farm benefit: crop revenues - input costs	€/ha	Market price	Revenues: regional crop sale prices (CARM, 2021b) Production costs: own estimation based on farmers interviews, following Fernández et al. (2020)
		Social demand for food security	€/kg	Choice experiment	Zabala et al. (2021b)
	Irrigation water (AES/AEDS)	Social demand for indirect irrigated agricultural benefits/costs	€/m^3	Choice experiment	Zabala et al. (2021b)
Regulating services	Emissions of contaminants to the atmosphere (AEDS)	Social cost of greenhouse gases emissions	€/t CO_{2eq}	Avoided social costs – benefit transfer	Revesz et al. (2017)
	Global climate regulation (AES)				
	Local climate regulation (AES)	Social demand for temperature reduction	€/1ºC descent	Choice experiment	Zabala et al. (2021b)
	Water purification and waste treatment (AEDS)	Social demand for the reduction of nitrate groundwater pollution	€/mg/L NO_3^-	Choice experiment	Zabala et al. (2021b)
	Soil maintenance (AES/AEDS)	Social demand for soil conservation	€/t soil	Choice experiment – benefit transfer	Rodríguez-Entrena et al. (2014)
	Biodiversity (AES/AEDS)	Social demand for biodiversity conservation in agroecosystems	€/p.p. bird richness	Choice experiment	Zabala et al. (2021b)
Cultural services	Culture, art and design (AES)	Social demand of cultural and heritable elements of agricultural landscapes	€/cultural element	Contingent valuation and choice experiment – benefit transfer	García-Llorente et al. (2012) Tagliafierro et al. (2013) Pappalardo et al. (2019) Martínez-Paz et al. (2019)
	Aesthetic values (AES)	Social demand for scenic landscape beauty	€/p.p. landscape heterogeneity	Choice experiment – benefit transfer	Arriaza et al. (2008)
	Opportunities for recreation and tourism (AES)	Social demand of enjoying recreation and tourism activities in agroecosystems	€	Choice experiment	Zabala et al. (2021b)
	Cognitive development and good living (AES)	Social benefits of agricultural employment generation	€/AWU	Shadow wage	European Commission (2014) SEPE (2020)

Table 4
AES and AEDS valuation. Irrigation water contribution to the agroecosystem value.

	AES / AEDS	Indicator / Value	Unit (~/ha year)	Ricote *Traditional agroecosystem*		Campo de Cartagena *Highly-intensive agroecosystem*	
				Rain-fed	Irrigated	Rain-fed	Irrigated
Provisioning services	Food (AES)	Crop yield	kg	239.58	34,600.00	94.04	49,120.00
		Market value	€	401.56	7063.02	67.13	10,767.37
		Non-market value	€	237.11	635.73	97.47	653.84
	Irrigation water (AES/AEDS)	Water	m^3		4909.40		6234.60
		Non-market value	€		82.35		-238.60
		$TEV_{provisioning}$	€	**638.67**	**7781.10**	**164.61**	**11,182.61**
Regulating services	Emissions of contaminants to the atmosphere (AEDS)	Carbon balance	t CO_{2eq}	14.60	29.73	14.74	24.46
	Global climate regulation (AES)	Non-market value	€	469.92	957.14	474.39	787.44
	Local climate regulation (AES)	Temperature reduction	ºC		-0.55		-1.20
		Non-market value	€		9.40		20.54
	Water purification and waste treatment (AEDS)	Nitrate concentration	mg/L NO_3^-	1.45	9.63	33.38	104.30
		Non-market value	€	-0.65	-6.36	-17.15	-96.64
	Soil maintenance (AES/AEDS)	Soil erosion	t soil	69.31	46.16	18.57	5.47
		Non-market value	€	-75.70	-50.41	-20.28	-5.97
	Biodiversity (AES/AEDS)	Bird species richness	%	100.00	100.00	83.70	73.82
		Non-market value	€	353.37	361.20	295.75	266.83
		$TEV_{regulating}$	€	**746.95**	**1270.97**	**732.70**	**972.00**
Cultural services	Culture, art and design (AES)	Non-market value	€	51.26	92.65	51.26	11.74
	Aesthetic values (AES)	Landscape heterogeneity	%	13.16	23.00	1.60	14.72
		Non-market value	€	29.08	50.82	3.54	32.53
	Opportunities for recreation and tourism (AES)	Outdoor recreation	0–1 Index	0.64	0.63	0.48	0.53
		Non-market value	€	100.14	97.17	75.21	82.14
	Cognitive development and good living (AES)	Employment	AWU	0.02	0.33	0.02	0.28
		Non-market value	€	100.70	1436.35	80.06	1203.95
		$TEV_{cultural}$	€	**281.18**	**1676.99**	**210.07**	**1330.36**
		TEV_{market}	€	**401.56**	**7063.02**	**67.13**	**10,767.37**
		$TEV_{non-market}$	€	**1265.24**	**3666.03**	**1040.24**	**2717.60**
		TEV_{total}	€	**1666.80**	**10,729.05**	**1107.37**	**13,484.97**

of the agroecosystem landscapes in our case study area. Agroecosystems provide an enjoyable landscape for activities of leisure and recreation, according to the social value attached to this ecosystem service by the local population (Zabala et al., 2021b). Finally, the presence of distortions in the labour markets, mainly derived from high and persistent unemployment rates, means that current wages do not represent the opportunity cost of labour. Instead, shadow wages account for the presence of such imbalances. It is thereby understood that the higher the unemployment rate, the lower the opportunity cost of labour, and the greater the social benefits of providing employment to society (SEPE, 2020). This approach was followed to estimate the social benefits of employment generation in agriculture, using the gap between the

Table 5
Irrigation water contribution to the agroecosystem value, the total economic productivity and the economic value of irrigation water.

Value	Unit	Ricote *Traditional agroecosystem*	Campo de Cartagena *Highly-intensive agroecosystem*
$\Delta TEV^{water}_{provisioning}$	€/ha/year	7142.42	11,018.00
$\Delta TEV^{water}_{regulating}$	€/ha/year	524.02	239.30
$\Delta TEV^{water}_{cultural}$	€/ha/year	1395.80	1120.29
$\Delta TEV^{water}_{market}$	€/ha/year	6661.46	10,700.23
$\Delta TEV^{water}_{non-market}$	€/ha/year	2400.79	1677.36
$\Delta TEV^{water}_{total}$	€/ha/year	**9062.25**	**12,377.59**
TEP_{water}	€/m^3	2.19	2.16
V_{water}	€/m^3	1.85	1.99

Table 6
Aggregated TEV by sub-system (€/year).

	Ricote *Traditional agroecosystem*		Campo de Cartagena *Highly-intensive agroecosystem*	
	Rain-fed almond	Irrigated lemon	Rain-fed almond	Irrigated lemon
Aggregated TEV_{market}	356,186	1539,738	291,625	38,967,102
Aggregated $TEV_{non-market}$	1122,268	799,195	4518,811	9834,989
Aggregated TEV_{total}	1478,454	2338,933	4810,436	48,802,091

shadow and current wages as a measure of such benefits.

4. Results

Irrigation water does contribute to the provision and economic value of both AES and AEDS. Table 4 shows the main results for both the biophysical and economic value indicators, distinguishing the source of the value -namely, the market and non-market values and the categories of services- as well as the contribution of water to the net provision of AES and AEDS. The total economic value is higher for the irrigated crops than for the rain-fed crops and it also depends on the kind of agroecosystem assessed. In particular, the total economic value of the traditional irrigated agroecosystems reaches 10,729 €/ha/year and that of the highly-intensive ones reaches 13,485 €/ha/year, whilst the values of the rain-fed agroecosystems are around 1650 and 1100 €/ha/year, respectively. The contribution of irrigation water is thereby more than 9000 €/ha for the traditional irrigated agroecosystem and 12,300 €/ha for the highly-intensive agroecosystem.

Regarding the provisioning services, the economic value of the food provided is mainly driven by the crop productivity; therefore, the highly-intensive irrigated agroecosystem is the most valued one, in both market and non-market terms. Notwithstanding, the greater use of irrigation water in this agroecosystem means that it represents one of the AEDS, thereby having a negative impact on social wellbeing. The non-linear social preferences for the supply of irrigation water to the agroecosystems in the case study area determine this economic cost, as Zabala et al. (2021b) revealed. In the case of the regulating services, the greater economic values correspond to the contributions to global climate regulation, biodiversity and water purification. Irrigated crops are able to sequester more carbon than rain-fed ones, this being the key factor that best explains the differences. In addition, the traditional irrigated agroecosystem also exhibits a greater economic value for the global climate regulation service, given the lower carbon footprint. The traditional agroecosystems contribute better to the biodiversity while barely showing groundwater pollution, as opposed to the highly-intensive agroecosystems. This reveals that there is room to improve the agricultural practices in the highly-intensive agroecosystems, to achieve a greater contribution to biodiversity and a lower one to groundwater pollution. Finally, in regard to the cultural services, the traditional agroecosystems show greater economic values for all the AES considered: the landscape beauty, the contribution to outdoor recreation and employment.

The distribution of the values of the agroecosystems among the categories of AES and AEDS depends clearly on the type of agroecosystem assessed. In rain-fed agroecosystems, regulating services represent the most important category of AES and AEDS, their relative importance being 50% of the total economic value in the case of the traditional agroecosystem and 75% in the case of the highly-intensive one. Provisioning services are less important in the case of the rain-fed agroecosystems, representing less than one-third of the total economic value for the traditional one and only 5% in the case of the highly-intensive one. However, the results are quite different for the irrigated agroecosystems. Provisioning services are the main AES, their relative importance reaching nearly 75% in the traditional agroecosystem and more than 80% in the highly-intensive one. Hence, water contributes not only to an increase in the total economic value of the agroecosystems,

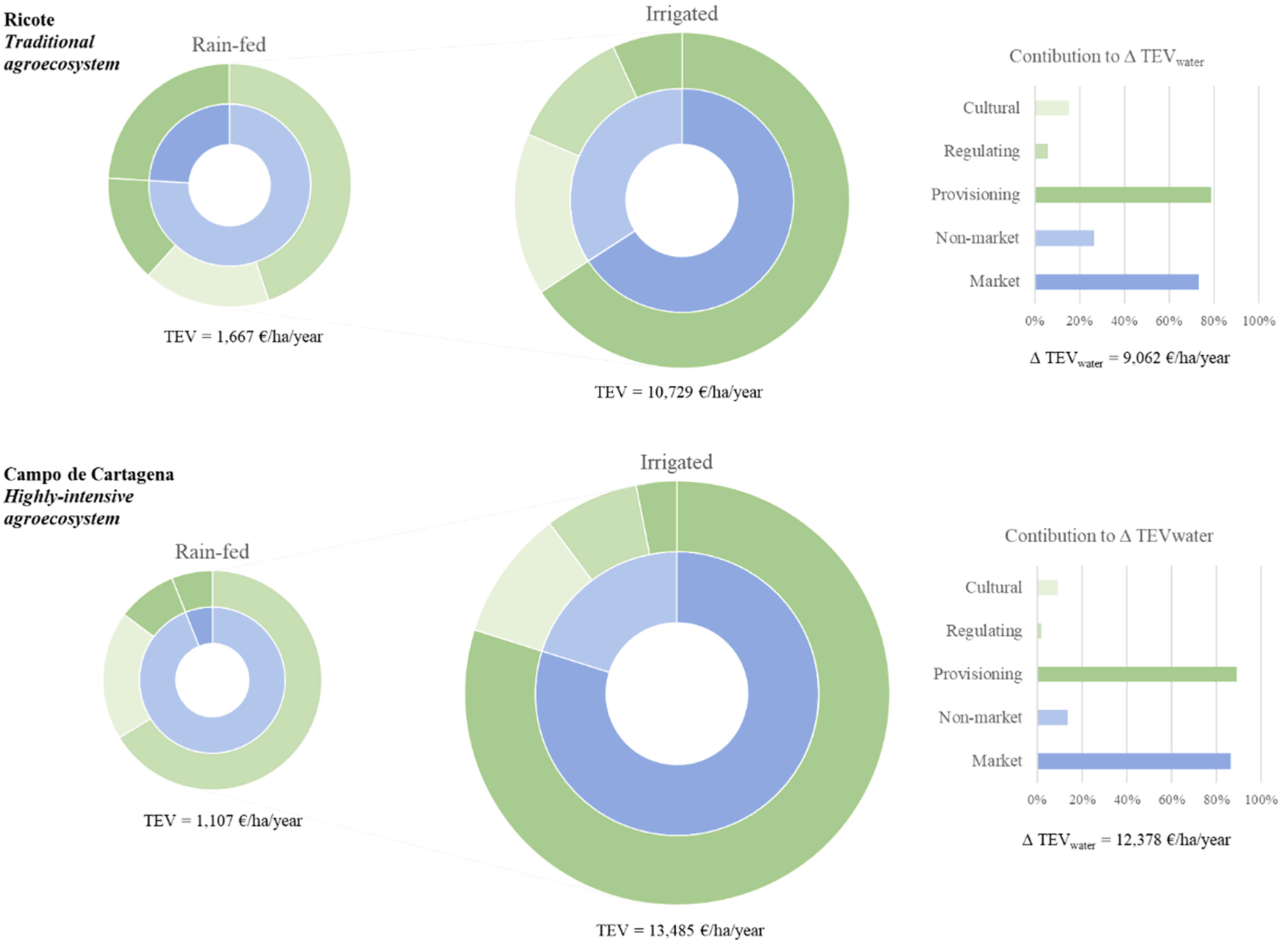

Fig. 3. TEV by sub-system and the irrigation water contribution. Distribution of the TEV among the categories of the AES and AEDS and the market and non-market values.

but also to a redistribution of the importance of the AES and AEDS provided.

As commented on before, water is a key element with regard to increasing the provision of AES and AEDS, whose net impact is entirely positive. Table 5 shows the contribution of irrigation water to the total economic value of the agroecosystems. Irrigated agriculture is responsible for increasing the provision of AES and AEDS, thereby, in net terms, increasing the contribution of agriculture to human wellbeing. This increase in the provision of AES and AEDS is present in all the groups of AES and AEDS, although it is mainly concentrated in the provisioning ones. Indeed, the increase in the value of the provisioning services due to irrigation water varies between 80% and 90%, depending on the agroecosystem. This is driven by the increase in food provision resulting from the supply of water for irrigation. Cultural services represent 10–15% of the total contribution of water to the value of AES and AEDS. This is mainly driven by the improvement in cognitive development and good living that agroecosystems provide due to employment generation. However, water produces only a slight increase in the value of regulating services, due to the positive net balance among the contributions of AES and AEDS. Indeed, water is behind the increases in carbon sequestration and temperature regulation and the reduction in soil erosion, which make a positive contribution to the net value of regulating services. In contrast, the nitrate concentration in aquifers and bird species richness indicators tend to worsen in the irrigated agroecosystems, in particular when there is intensive use of agricultural water. This is revealed by the contribution of water to the value of the regulating services, which reaches 524 €/ha/year for the traditional agroecosystem, but only 239 €/ha/year for the highly-intensive one.

The results for the total economic productivity of irrigation water enhance the assessment. Indeed, the traditional and highly-intensive irrigated agroecosystems exhibit a similar total economic productivity of water, 2.19 €/m^3 and 2.16 €/m^3, respectively. However, the sources of this total economic productivity are not equally distributed. The market contribution is the greatest one, being 65–80%, depending on the agroecosystem, and being highest for the highly-intensive agroecosystem. The same applies to the distribution of the water economic productivity when distinguishing among the different groups of AES and AEDS. The value of the provisioning services contributes 72–82% of the water economic productivity, while that of the cultural services represents 10–16% and that of the regulating services 8–12%. These ranges differ also between the traditional and highly-intensive irrigated agroecosystems given that the traditional one provides higher values of the regulating and cultural services, in contrast to the highly-intensive one, where the provisioning services provide higher economic values.

The economic value of irrigation water is 1.99 €/m^3 in the highly-intensive agroecosystem, slightly higher than in the traditional agroecosystem (1.85 €/m^3). Again, the market component of irrigation water determines this difference. Notwithstanding, the contribution of non-market AES and AEDS to the economic value of the water is greater in the case of the traditional agroecosystem. This reflects the duality in the case study area. A highly-intensive irrigated agroecosystem with a higher market value of irrigation water coexists with a traditional irrigated agroecosystem in which irrigation water that has a greater non-market value due to its contribution to regulating and cultural AES and AEDS. Therefore, the intensity of the use of irrigation water influences not only its final value, but also the kind of contribution it makes to human wellbeing.

The economic values estimated for the analysed sub-systems allow us to determine the overall impact of agriculture on human wellbeing in the case study area. Table 6 shows the aggregated TEV for each sub-system. The aggregated TEVs of the agroecosystems in the Campo de Cartagena are notably greater, given the large extension occupied by lemon crops and the higher economic value of the irrigated agroecosystems. Hence, here, the irrigated agroecosystems provide nearly 49 M€/year of net benefits to society, which contrasts with the value of 2.3 M€/year for the irrigated agroecosystems in Ricote Valley. Changes in the crop distribution will necessarily change these economic values.

5. Discussion

Water boosts the contribution of agriculture to wellbeing. The integrated market and non-market economic valuation of AES and AEDS in rain-fed and irrigated semi-arid western Mediterranean agroecosystems shows the importance of irrigation water with regard to enhancing the provision of AES and AEDS, and thereby its contribution to human wellbeing. Also, the intensity of the use of agricultural water has been tested, using two different types of agroecosystems as case study areas: a traditional irrigated agroecosystem and a highly-intensive irrigated agroecosystem. The results reveal that irrigation can increase the values of irrigated agroecosystems so that they are six to twelve times those of rain-fed ones, depending on the intensity of the use of irrigation water. The economic values of the AES and AEDS, understood as a summary of the net contribution of agriculture to human wellbeing, reveal that irrigation water is crucial not only for increasing land productivity, but also for social wellbeing. This is key for agricultural water management. Irrigation water should be thereby managed for increasing the net value of agroecosystems, which ultimately is converted into increases in social wellbeing. Enhancing the provision of AES while mitigating AEDS could be ensured by both redistributing irrigation water between agroecosystems and adopting new agricultural practices, such as regulated deficit irrigation or precision agriculture, that support it.

The economic value of irrigation water exceeds the current market price of irrigation water in the study area: 0.30–0.40 €/m^3, depending on the agroecosystem considered. The overall value of irrigation water reflects, therefore, not only its contribution to the value of the crop yield, as most studies usually show (e.g. Berbel et al., 2011; Ziolkowska, 2015, Bierkens et al., 2019), but also its overall contribution to social wellbeing. When the market and non-market irrigation water contributions to society are considered, the value of irrigation water rises to 1.85–1.99 €/m^3. These values contrast sharply with those found in the literature for citrus in Spain: around 0.35 €/m^3 (Bierkens et al., 2019), 0.43 €/m^3 (Berbel et al., 2011) and 0.50 €/m^3 (Rigby et al., 2010). Indeed, most of

Table 7

Agricultural water management scenarios.

		Ricote *Traditional agroecosystem*		Campo de Cartagena *Highly-intensive agroecosystem*		
		Rain-fed almond	Irrigated lemon	Rain-fed almond	Irrigated lemon	Total
Scenario 0 Current situation	ha	887	218	4344	3619	
	Aggregated TEV$_{total}$ (€/year)	1,478,454	2,338,933	4,810,436	48,802,091	57,429,915
Scenario 1 Improved situation	ha	1105	–	4172	3791	
	Aggregated TEV$_{total}$ (€/year)	1,841,817	–	4,620,341	51,116,959	57,579,117
Scenario 2 Regulating + Cultural	ha	–	1105	5042	2921	
	Aggregated TEV$_{total}$ (€/year)	–	11,855,601	5,583,897	39,383,341	56,822,839
Scenario 3 Climate change	ha	1105	–	6774	1189	
	Aggregated TEV$_{total}$ (€/year)	1,841,817	–	7,501,692	16,029,548	25,373,057

these values for irrigation water are close to the market price of irrigation water in each case. This difference reveals the significance of considering the non-market side of irrigation water, whose value is important for society.

In this study, the greatest contribution of water is to the market value of AES. Whilst in the rain-fed agroecosystems the non-market value of the AES and AEDS represents the greater part of the TEV, the market value provides the most significant part of the TEV in the irrigated agroecosystems. This is mostly due to the increase in crop productivity, which is translated into the value of the provisioning services. Indeed, most of the agroecosystems valuations reported in the literature show the prevalence of market values over non-market ones (e.g. Sandhu et al., 2008; Ghaley et al., 2014; Hardaker et al., 2020). The TEV of water depends on how much irrigation water is supplied to the agroecosystem, as Zabala et al. (2021b) revealed. So, supplying water to the traditional agroecosystem is understood as a positive contribution to human wellbeing, namely, as a benefit, whilst supplying water to the highly-intensive agroecosystems, given the high water consumption, is categorised among the AEDS, therefore having a social cost. Fig. 3 shows the relative importance of each category of the AES and AEDS to the TEV, as well as their importance in the contribution of water to the AES and AEDS. In addition, all of the AES and AEDS are also influenced by the contribution of water. The cultural services -in particular, employment generation and aesthetic values- are the ones most influenced by this contribution, followed by the regulating services. Carbon sequestration and the reduction of soil erosion rates -that is, the reduction of one of the AEDS- comprise the positive contribution of water to the regulating services. However, on the negative side, water could also contribute to an increase in groundwater pollution and a loss of biodiversity, given the induced intensity that irrigated agriculture may impose. Nonetheless, the results show that there is room for actions to reduce these negative impacts and even to try to improve the contribution of irrigated agriculture to human wellbeing.

The monetary values, which summarise the current wellbeing impact of the different types of agroecosystems, are of high importance in the improvement of agricultural water management (Gordon et al., 2010). Thus, in order to compare alternative solutions and scenarios for policy design, Table 7 shows a set of scenarios for agricultural water management. This allows one to evaluate if there is room to increase the value of the agroecosystems by modifying the current water management. By maintaining the current irrigation water supply to agriculture, water could be managed in a way that increases the TEV in the Region of Murcia as a whole. Assuming that water can be easily conveyed between irrigated sub-systems, which is indeed the case, the solution that provides the greatest TEV for the entire region implies that the entire water supply for irrigation is moved to the Campo de Cartagena, given its higher economic productivity.

When water is not a limited resource, all types of agriculture would be transformed into irrigated agriculture, increasing significantly the overall impact on human wellbeing, whose aggregated TEV would rise to 119 M€/year. However, despite its socioeconomic desirability, this situation is not realistic, given the current water availability. Nevertheless, even with the water currently available, the TEV could be enhanced. Scenario 1 shows an economic gain of 149,202 €/year if the aggregated TEV is maximised with the current water resources. However, this would imply transformation of the traditional irrigated agroecosystem into a rain-fed one, despite the superior regulating and cultural services the former provides.

Irrigation water could also be managed to foster some AES, or mitigate some AEDS, by promoting the expansion of irrigated agroecosystems in one or another agroecosystem. Therefore, if policy makers decide to promote regulating and/or cultural services, instead of provisioning ones, water for irrigation should be distributed in a way that fosters irrigated farmland in the traditional agroecosystem. In this case, water resources should be allocated firstly to the traditional agroecosystem, with the remaining water allocated to the highly-intensive agroecosystems. This is shown in Scenario 2. However, despite the promotion of regulating and cultural AES, and the mitigation of their respective AEDS, the TEV in the case study area would ultimately be lower than in the current situation.

Climate change would compromise the availability of water resources, forcing agricultural stakeholders to adapt agriculture and mitigate its impact on human wellbeing. Climate change is expected to impact on water availability in the case study area by reducing: (1) the natural water resources in the region; (2) the amount of water transferred from the Tajo river basin. It is thought that natural water resources obtained from the Segura river would drop by 40%, while inter-basin transfers from the Tajo river could be reduced by 70% (Pellicer-Martínez and Martínez-Paz, 2018). This Scenario 3 would necessarily reduce the extension of irrigated sub-systems, which would be replaced by rain-fed crops. This would be rapidly translated into a reduction of the aggregated TEV of the agroecosystems and, therefore, into a reduction of the impact of agriculture on human wellbeing. Notwithstanding, actions could be taken in the context of agriculture and farmers' practices in order to reverse or, at least, try to mitigate this negative impact on wellbeing.

The total economic water productivity is the indicator that can best summarise all the contributions of AES and AEDS to the economic value. Hence, in order to increase the TEV of agriculture in a context of water scarcity, the total economic productivity of irrigation water should be maximised (Fernández et al., 2020). There are different ways to affect this indicator: (1) increase the efficiency of the use of irrigation water, namely, reduce the water supply for crop irrigation, while minimising its impact on crop production; (2) increase the provision of AES, which will be translated, ceteris paribus, into an increase in the TEV of the sub-systems; (3) reduce the provision of AEDS, which will increase, ceteris paribus, the TEV of the sub-systems. To promote this net gain in wellbeing, the adoption of alternative agricultural practices is essential.

Changing the way farmers act and connect to agroecosystems -namely, their agricultural practices- is the basis for ensuring an improvement in the economic water productivity, both the market and non-market water productivity. The first action proposed is to reduce the water supply for irrigation without compromising the output; that is, the implementation of regulated deficit irrigation (Fernández et al., 2020). Specifically, within the irrigated sub-system in the Campo de Cartagena, there is room to implement such regulated deficit irrigation strategies, given the great consumption of irrigation water in the area (Saitta et al., 2021). In addition, as previously mentioned, another way to increase the economic water productivity is to enhance the provision of AES, without compromising AEDS and irrigation water use. Agricultural practices can be modified in traditional irrigated agroecosystems in order to increase food provision. In highly-intensive agroecosystems there is more room to improve the biodiversity, landscape beauty and outdoor recreation. Therefore, precision agriculture could be a way to increase land productivity in irrigated sub-systems of traditional agroecosystems (Jenrich, 2011; Fountas et al., 2015). Besides, agricultural practices to promote biodiversity, such as the establishment of perimeter hedgerows (Assandri et al., 2016; Heath et al., 2017) or biological pest control (Bianchi et al., 2006; Crowder and Jabbour, 2014), can be applied in the Campo de Cartagena. Alternatively, reduction of the provision of AEDS is also a way to increase the net value of agroecosystems. Conservation agriculture, based on reduced tillage and cover crops, crop diversification and the use of green manure are examples of agricultural practices that would reduce soil erosion (Eekhout and de Vente, 2019), increase carbon sequestration (Aguilera et al., 2013; Sánchez-Navarro et al., 2019) and diminish groundwater pollution (Hunt et al., 2019).

In order to ensure that such these agricultural practices are widely adopted by farmers, the development and implementation of private and public actions and instruments might support their enhancement. The range of instruments available for encouraging farmers to implement new agricultural practices depends on the intensity of changes that they may imply with regard to their current practices. For instance, the most common public instrument is the use of direct subsidies to farmers, usually applied to compensate the implementation costs of new practices, or even incentivise them monetarily (Villanueva et al., 2017). However, not only monetary incentives are available (Cortés-Capano et al., 2021). There are a wide range of non-monetary instruments, such as technical support, training and courses, or labelling incentives, among others, that can also be applied from the public side to incentivise the adoption of agricultural and water saving practices by farmers. Even collective schemes can be also publicly incentivised using the current social infrastructure, for instance, through irrigation communities, at a lower cost for public budgets (Kaczan et al., 2017). On the other hand, new business models, based on circular economy and sustainability, could be seen as an opportunity for farmers to adopt agricultural practices and promotes the provision of AES whilst mitigating AEDS (Daou et al., 2020).

In this way, the results of this work allow improving the design and implementation of agricultural policies, which can be applied to other Mediterranean agroecosystems with similar characteristics, as is the case of intensive agriculture in the island of Crete (Greece) (Kourgialas et al., 2018) and Souss-Massa Region (Morocco) (Abdelmajid et al., 2021) and traditional agriculture in Valencia (Spain) (Melo, 2020) and Umbria Region and Veneto Plain (Italy) (Torquati et al., 2017; Tempesta, 2010).

6. Conclusions

Agricultural irrigation water is a key input not only for agriculture, but also for agroecosystem functioning, since it impacts AES and AEDS flows to society and thereby human wellbeing. This integrated market and non-market valuation of AES and AEDS for rain-fed and irrigated agroecosystems has revealed a contribution of water to the value of agroecosystems, which could be understood as the irrigation water contribution to human wellbeing. The higher values of irrigation water, in relation to ecosystem services, reflect the need to promote more efficient uses of water, given its positive impacts on society.

The analysis of the contribution of water to the value of irrigated agroecosystems has revealed the potential of irrigation water to increase the economic and social value of agriculture, thereby exceeding the market value of the agricultural output. Irrigation water contributes to the TEV of all categories of AES and AEDS, mainly provisioning services, but also regulating and cultural. The intensity of the water use also influences the outcomes, agroecosystems with more intensive use being greater providers of provisioning AES, whilst agroecosystems with less intensive use are greater providers of regulating and cultural AES.

Appropriate agricultural water management and agricultural practices are crucial to ensure social wellbeing. Efficient and socially accepted water and agricultural policies should benefit the TEV of water, to justify the promotion of agricultural practices that enhance the provision of AES and mitigate the generation of AEDS. In a context of growing pressures on water resources, both the market and non-market economic water productivity should be boosted in order to increase the social wellbeing derived from the use of irrigation water.

Economic instruments, such as water markets, could be used when water re-distribution (between irrigation areas and agroecosystems) would increase the total social wellbeing provided by agriculture. The defining variable for setting the rates and volumes exchanged should be guided not only by the marginal productivity associated with the provision of AES, as is usual, but by the total economic water productivity of each agroecosystem. The total economic productivity of the irrigation water for the buyers should not be lower than the total economic water productivity of the sellers, in order to ensure that a compensation point could be reached, with public subsidies and tax on the exchange rates to offset the provision of non-market AES and AEDS.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This work was supported by the AgriCambio project (Grant PID2020-114576RB-I00 funded by MCIN/AEI/ 10.13039/501100011033). José A. Zabala, Víctor Martínez-García and José A. Albaladejo-García acknowledge the financial support from the Spanish Ministry of Education and Personal Training (FPU 16/03473; FPU19/05143; FPU 16/03562).

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