



Full length article

Social indicators of ecosystem restoration for enhancing human wellbeing



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ABSTRACT

This study implements the ecosystem service framework to link the concepts of farming activity and ecosystem restoration within the circular economy. It proposes a method for identifying social indicators of ecosystem restoration that can be taken into account in the transition towards more circular and sustainable agricultural systems. Using a case study located in semi-arid Mediterranean landscapes, we conducted a social sampling with 350 respondents to explore how an almond tree restoration changes perceptions and preferences for ecosystem services, and how these socio-ecological changes translate into indicators of natural capital and human well-being. Results not only indicated that the almond tree restoration induced changes in people's preferences and perceptions for ecosystem services, such as an increase in ecosystem service diversity (i.e., local identity and erosion control), but they also demonstrated how the social and cultural benefits associated to ecosystem services can be used as indicators of human well-being (i.e., human health and access to goods). We suggest that the inclusion of social indicators of ecosystem restoration must be included in policies and initiatives for a transition to circular economy, and to achieve the challenges of the UN Decade on Ecosystem Restoration.

1. Introduction

Circular economy (CE) seeks to decouple economic growth from the consumption of resources, conserving the product and material value for as long as possible (Kirchherr et al., 2017; Chowdhury et al., 2020), by keeping resources in circular movements that connect different production and consumption systems (Hanumante et al., 2019). However, using such definition, only 9% of the world economy is currently circular (Barros et al., 2020). The European Union (EU) is aware that the CE will make a decisive contribution to achieving climate change neutrality by 2050 while ensuring its long-term competitiveness. For this reason, it must accelerate the transition to a regenerative growth model that keeps resource consumption within the limits of the planet, reducing its

consumption footprint and doubling the usage rate of circular material in the next decade (Muscio and Sisto, 2020). To meet this objective, the EU has developed a new Action Plan for the Circular Economy 2020, which seeks to benefit people, regions, and cities, contribute to climate neutrality and promote research, innovation, and digitalisation, achieving by 2030 the Sustainable Development Goals (European Commission, 2020a). One of the main initiatives of this plan is to identify the effects of circularity on climate change mitigation and adaptation measures, such as restoring ecosystems, reforestation, and strategies that enable carbon sequestration in agriculture (European Commission, 2020a). Additionally, recent research argues the importance of having well-designed and effective indicators in the transition from a linear to a circular economy (Di Maio and Rem, 2015). However,

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there is a gap in CE research in this regard, due to the lack of works that develop or discuss CE indicators (Elia et al., 2017). Therefore, it is fundamental to develop sets of well-designed, effective indicators to support robust decision-making processes that ensure an agricultural sustainable transition from a linear economy to a CE (Aznar-Sánchez et al., 2020).

Ecological or ecosystem restoration, i.e., natural or assisted recovery of ecosystems taking into account their resilience, functionality and sustainability (Higgs et al., 2018), is a clear strategy of integration between the above mentioned circularity and climate change mitigation and adaptation measures (Muscio and Sisto, 2020). It contributes to the restoration of biodiversity and natural capital and facilitates the transition towards a sustainable future by the promotion of reduce, reuse, recycling and recovery of resources and products (Priyadarshini and Abhilash 2020). Furthermore, ecological restoration is included in the EU's Biodiversity strategy for 2030, whose main objective is to protect nature and reverse ecosystem degradation, putting Europe's biodiversity on the road to recovery by 2030. Specifically, the strategy sets out to create an EU nature restoration plan for 2030, addressing the main drivers of biodiversity loss (European Commission, 2020b).

One strand of ecological restoration is the agroecosystem restoration, using diversified crops on degraded land, benefiting restoration by increasing the provision of ecosystem services (benefits people get from nature) such as soil fertility, promoting sustainable agriculture and rural participation (Priyadarshini and Abhilash 2020). In addition to helping communities recover their degraded ecosystems, ecological restoration boosts agricultural productivity, while maintaining resource efficiency, with positive implications for food sovereignty (Wade et al., 2008). In Europe, over the last 50 years, the agri-food industry has become more intensive, based on a growth and increasing production efficiencies model, which has often led to food production being environmentally unsustainable (Muscio and Sisto, 2020). It is, therefore, necessary to change from a linear model of agricultural intensification to a circular model that significantly reduces these negative pressures on the environment, reducing inputs, and undesired outputs and externalities (Oteros-Rozas et al., 2019). Circular models that respond to the objectives of the European Farm to Fork Strategy, a key element of the European Green Deal, which aims to reduce the environmental and climate footprint of the EU food system, strengthen its resilience, ensure food security in the face of climate change and biodiversity loss, and lead a global transition towards competitive sustainability (European Commission, 2020c). The Farm to Fork Strategy makes clear that food systems cannot be resilient to crises if they are not sustainable. While agroecology is a growing field of research and practice, for the purposes of this paper, we will refer to the wider term of ecological restoration, but note that agroecology can be included therein.

While attention has been given to economic and environmental indicators, one of the challenges of the ecological restoration within CE is to integrate the social aspect of sustainability. Specifically, it is not clear how social well-being is directly improved through CE implementation (Ngan et al., 2019). For this reason, the introduction of new indicators that include the environmental and social aspects of progress is fundamental to influence social perceptions, public policies and support social actors that promote economic transformation (Fioramonti et al., 2019). This is the aim of the Beyond GDP initiative promoted by international organisations, such as the United Nations (Bleys, 2012). They claim that well-being indicators would allow us to better connect global governance with changes in the economy, thus providing a more up-to-date picture of prosperity (as opposed to GDP), giving greater visibility to the economic stakeholders that are leading the way in this economic transformation and supporting the transition to a good Anthropocene (Fioramonti, 2017). Dasgupta report (2021) lends support to this initiative in his report on the Economics of Biodiversity in which it is highlighted the need to change our measures of economic success, which for the most part exclude Nature from economic models. Demonstrating the need for the inclusion of Natural capital to guide us on more

sustainable pathways. This report emphasises that GDP is a limited measure and one that hails back to previous perceptions of the importance of produced capital and human capital over natural capital. By not taking into account the depreciation of the natural environment, the pursuit of unsustainable economic growth and development has been encouraged in both private enterprise and public policy. This report also sets out a careful argument for an inclusive measure of wealth and natural capital accounting, one that recognises and includes natural assets and services in our economies, and keeps in mind the well-being of current and future generations. In addition, in developing a natural capital accounting framework, the movement of natural capital over time may be calculated, which is necessary for assessing sustainability and for policy analysis. (Dasgupta, 2021). The same applies to ecological restoration, where there is little knowledge about the extent to which people benefit from the restoration results or what social interactions result in this process (Martin and Lyons, 2018). Consequently, these types of metrics or indicators are important for practitioners, conservation managers, local communities and policymakers, who need to demonstrate the social contributions of restoration and must make decisions about resource management at different scales (Moseley and Reyes 2008; Higgs, 2012).

These well-being social indicators can be identified through the ecosystem service framework (ES) proposed by the Millennium Ecosystem Assessment (MEA) 2005. The MEA (2005) report identified agroecosystems as a vulnerable situation due to the decline of cultural values and regulating ecosystem services (MEA, 2005). An assessment of the ES provided by ecological restoration processes can be done in different ways (Quintas-Soriano et al., 2018a; Pérez-Ramírez et al., 2019). One way is to measure biophysical parameters that reflect changes in biophysical structure and that are function-driven by management decisions or environmental changes (Quintas-Soriano et al., 2019; Olander et al., 2018). Another way is through socio-cultural and economic valuation measures that reflect and translate the impact of ES on human well-being (Castro et al., 2013; García-Llorente et al., 2015). This latter can be done through the analysis of the perceptions and preferences of locals and other stakeholders about the ES provided by a given landscape (Martín-López et al., 2007a; Castro et al., 2011; 2019). This type of assessment can be used to obtain social indicators that identify social benefits, in terms of contributions to human well-being or the diverse values local communities place on restoration process (Quintas-Soriano et al., 2018a; Narducci et al., 2019). In addition, if we consider the tenants of Beyond GDP, we can see the connection between agricultural activity and ecological restoration. Increasing intensified agriculture is based on a growth model, with every increasing demands for higher production. Yet the regeneration of natural systems, which is compatible with agricultural activity, highlights other non-economic goods that are generated for both the natural environment and society.

This paper conducts a socio-economic assessment of the ES gained through an ecosystem restoration process conducted in a rural region of south-eastern Spain with the goal of identifying social indicators that enhance natural capital. Specifically, we aimed to explore social perceptions and preferences for ES as social indicators of the impacts of ecosystem restoration to wellbeing. To do so, we first examined factors that explain social awareness of the benefits associated to ecological restoration with almond tree. Secondly, we explored the social perceptions regarding ES delivery and ES change associated to almond tree restoration. Third, we compared social preferences for and perceived vulnerability of ES before and after the ecological restoration. Fourth, we assess how diverse socio-demographic factors influence ES perceptions and preferences. Finally, we examined the linkages between preferences for ES and the maintenance of human wellbeing.

2. Methods

2.1. Study area

The case study was conducted in the Los Vélez region, a semi-arid area of southeast Spain, in the Almería province. Los Vélez is a rural region characterised by its large extensions of ecological and conventionally cultivated almond trees, which have boosted its economy and influenced its culture (Castro et al., 2018a). It has a warm, dry Mediterranean climate, with average annual temperatures of 12° and 15 °C and with an annual average rainfall of 200–350 mm per year (Castro et al., 2018b; Quintas-Soriano et al., 2014; Armas et al., 2011). The region includes four municipalities (Vélez-Blanco, Vélez-Rubio, Chirivel, and Maria) around the Sierra Maria-Los Vélez Natural Park (Valenciano, 2007). Its total population is around 12,500 inhabitants, with an equal distribution of men and women (50% men, 50% women) the majority of which are located in the Vélez-Rubio municipality. In the past, traditional agriculture was based on cereal crops. However, since the '70s, almond tree cultivation on unirrigated land has been a way to improve the region's development due to its high profitability (Navarro-López et al., 2012). In addition, the introduction in recent decades of ecological almond tree varieties has made this crop the most planted in the region, with more than 19,484 ha (IECA, Instituto de Estadística y Cartografía de Andalucía 2020).

The restoration process was carried out within the framework of EU LIFE The Green Link project (<https://thegreenlink.eu/>). The Green Link aimed to restore desertified areas with an innovative tree growing method to increase resilience. As a restoration area, we used a private plot (El Ciruelo) located in the southern part of the Sierra María-Los Vélez Natural Park (Fig. 1) to plant over 3000 almond trees of the Guara and Lauranne varieties. This land plot was chosen mainly because of the landowners' willingness to cooperate in the LIFE project and because of the agricultural activities they carry out on the surrounding plots which allowed us to compare our results. Other auxiliary species such as rosemary and aromatic plants were planted around the almond trees to attract pollinators and diversify the crop. The ecological almond tree varieties are characterized by their late flowering, which makes them more resistant to frost. Their low water requirements, high resistance to drought, high productivity, and good fruit quality (Castellví et al., 2007) also characterize them.

2.2. Social sampling strategy and questionnaire design

In order to obtain a convenient sample of the local population of the region, we conducted 350 face-to-face surveys before and after the restoration process. The pre-restoration surveys took place in July 2017 and the post-restoration surveys in July 2019. The sampled population was selected semi-randomly in an effort to represent the heterogeneity of ES beneficiaries (Castro et al., 2016 a,b). The social sampling covered a wide range of stakeholders, from primary sector workers, traders, tertiary sector workers and public administration workers, amongst others (Castro et al., 2011). As sampling locations, the populated centres of the four municipalities of the region were visited (Maria, Chirivel, Vélez Blanco, and Vélez Rubio). The social sampling for the pre- and post-restoration identified that most of the respondents (over 80%) were from the Vélez region. Overall, 60% were men and 40% women, with an average age ranging from 41y/o (pre-restoration) to 32y/o (post-restoration) (Table 1). The population surveyed before and after restoration were not the same, although they represented similar stakeholders.

Respondents were informed that all the answers were anonymous, and that there were no right or wrong answers. We had no contact with

Table 1
Socio-demographic characterization of the Los Vélez region.

Categories		Pre-restorationN = 249	Post-restorationN = 101
Gender	Female	98	37
	Male	151	64
Age	Mean (\pm SD)	41.7 (\pm 12.7)	32.3 (\pm 15.9)
Place of residence	Los Vélez Region	82.7%	64.4%
	Other municipalities	17.3%	35.6%
Rural development job	Yes	60.2%	34.7%
	No	39.8%	65.3%
Land ownership	Lease	15.0%	3.9%
	Ownership	53.6%	26.2%
	None	31.4%	69.9%
Educational level	University	40.2%	17.8%
	Professional formation	10.8%	26.7%
	High school	9.6%	18.8%
	Secondary school	14.1%	21.8%
	Primary school	18.5%	5.0%
	Others	6.4%	9.9%

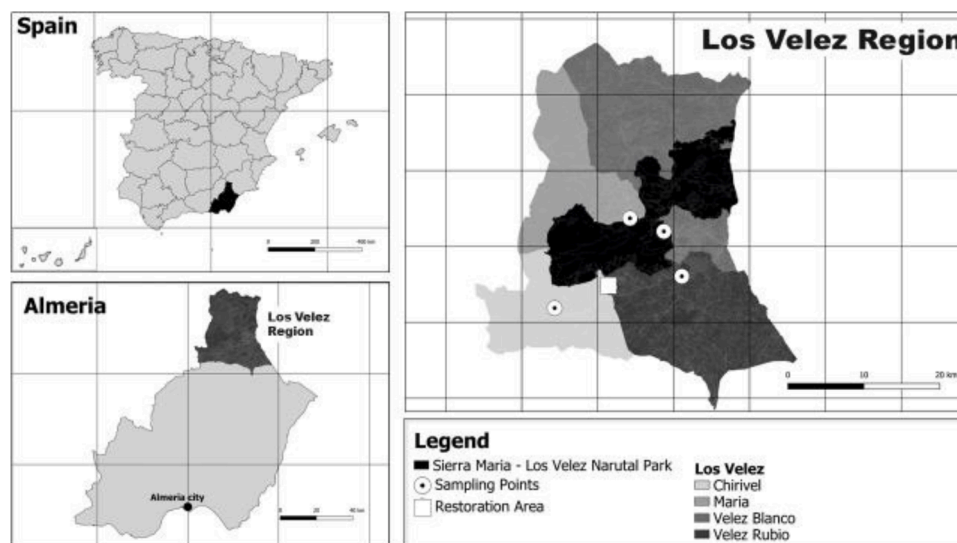


Fig. 1. Location of the study area and sampling points (i.e. locations where the face-to-face surveys were conducted).

any respondents before our surveys (Narducci et al., 2019). The questionnaire included four main sections; section A included questions that used a free-listing technique for exploring ES, section B for exploring ES preference and ES trend; section C for exploring perceptions toward crops, and section D for collecting socio-demographic information of respondents (see Appendix A in Supplementary Data; based on Castro et al., 2016).

2.3. Perception and preferences for crop cultivation in the region

We examined both social perceptions and preferences regarding the region's traditional crops by using a free-listing and ranking technique, respectively (Quintas-Soriano et al., 2018b; Castro et al., 2015a). First, respondents were asked to identify examples of those crops considered as most beneficial to the well-being of the region. Responses were coded into different crop categories (i.e., almond, olive, pistachio, cereal, pine, others). Secondly, we used a panel with six specific crops (i.e., almond, olive, cereal, pistachio, tamarix and pine; see Appendix B1) and asked respondents to select and rank the four most important, assigning them a value from one (least important) to four (most important), and describing motivations supporting their choice. Finally, in order to specifically understand public support for ecological and traditional almond cultivation, we explored the perceptions regarding its contributions to the development of the region. Responses were coded into six categories (i.e., environmental benefits, economic, aesthetic, food supply, employment generation, and tradition) to characterize the social awareness toward ecological restoration with almond tree.

2.4. Social perception, preferences and perceived trends of ecosystem service associated to ecological restoration

The analysis of ES perceptions was carried out in the pre-restoration and post-restoration phases. Here we define social perception analysis as an exercise in which it is explored the public knowledge about the benefits that nature provides to people (or ecosystem services) through a free-listing technique (Martín-López et al. 2007a, b; Castro et al., 2011, 2013). This technique is commonly used to explore all possible benefits that people associate with a particular ecosystem or species (García-Llorente et al., 2011a, 2020; Quintas-Soriano et al., 2016, 2018b). Responses were coded as ES, excluding ambiguous responses and those that did not fit any classification (Martín-López et al., 2011; García-Llorente et al., 2011b). Similar responses were grouped into a single category corresponding to a given ES. Finally, we analysed the percentage of responses for each ES category (provisioning, regulating, and cultural) and for each ES classes (Quintas-Soriano et al., 2020).

The analysis of preferences and trends of ES was carried out by analysing the social importance and perceived trend placed on ES (Narducci et al., 2019). Preferences for and trends of ES were explored during the pre-restoration and post-restoration phases in order to reflect the importance that people place on revealed benefits considered as important for human well-being maintenance (Castro et al., 2011, 2013). Respondents were shown a panel of 15 ES; five per category (provisioning, regulating and cultural; see Appendix B). ES were selected from previous research in the region (Castro et al., 2015a; García-Llorente et al., 2015). From 15 selected ES, we asked respondents to rank the four ES that they considered as most important to maintain human well-being in the region, and they were asked to express the motivations behind their choices. Thereafter, for the four ES identified as most important, the perceived ES trend was analysed by asking respondents if they believed an individual ES supply had been decreasing, increasing, stable, or whether they did not know, over the past ten years ("don't know" responses answers were excluded from the analysis). Perceived trends reflect the degree of vulnerability people attach to the ES they have identified as most important. The perceived importance of ecosystem services was coded as 0 = not chosen, 1 = less important, 2 = slightly important, 3 = very important and 4 = most important. The

perceived trend of ecosystem services was coded as 1 = decreasing, 2 = stable, 3 = increasing. Averages of the importance and trends of ecosystem services were estimated and reclassified into very important, important, slightly important and less important (Castro et al., 2015b).

The ES state throughout the ecological restoration process was estimated by exploring the relationships between ES importance and perceived trend (Iniesta-Arandia et al., 2014). We considered four ES states based on different levels of importance and vulnerability. Vulnerability levels were estimated from ES trends, so an ES identified with a decreasing or increasing trend was considered as vulnerable and not vulnerable, respectively. ES were classified using the median number of respondents and plotted into four state groups: (1) critical ES (i.e., ES perceived as important and vulnerable); (2) important and not vulnerable; (3) vulnerable and not important; and (4) not important and not vulnerable.

2.5. Socio-demographic factors influencing perception of ecosystem services

Influence of socio-demographic factors on ES perceptions (i.e., provisioning, regulating, and cultural) was analysed by using non-parametric tests of Kruskal-Wallis and Mann-Whitney U. Socio-demographic factors included age (under 40 vs. over 40), gender (female vs. male), place of residence (region residents vs. residents from others municipalities), level of education (i.e., university, professional formation, high school, secondary school, primary school). In addition, other economic factors such as rural development job (yes or not) and land ownership (i.e., lease, ownership or none) were analysed (Martín-López et al., 2012; Quintas-Soriano et al., 2014, 2016; García-Llorente et al., 2012, 2015; Castro et al., 2011).

2.6. Relationship between ecosystem service and human wellbeing

Linkages between ES categories (i.e. provisioning, regulating, and cultural) and components of human wellbeing were identified by exploring human motivations in ES ranking (Quintas-Soriano et al., 2020) (see Section 2.3). Specifically, motivations expressed in ES preferences were coded according to components of well-being (MEA 2005). Ambiguous answers and those that did not fit any classification were excluded. Motivations were grouped into four components and sub-components of well-being, including security (personal safety, secure resource access and security from disasters), the basic material for a good life (adequate livelihoods, sufficient nutritious food and access to goods), health (strength, feeling well and access to clean air and water), and good social relations (social cohesion, mutual respect and ability to help others). Finally, significant differences amongst human well-being components and sub-components were analysed using a Kruskal-Wallis test, and the results for each ES category were compared between pre and post-restoration.

3. Results

3.1. Perceptions and preferences toward crops and almond tree production

Overall, the analysis of perception and preferences for crops identified the almond tree as the most valuable crop in the region, followed by cereal and olive (Fig. 2). Both the free-listing and ranking identified almond trees as the most important crop (Fig. 2). Additionally, the analysis of preferences also identified these crops as the most preferred by locals, with an average importance of 3.26 for the almond tree, 2.34 for cereal and 2.07 for olive (Figure. S4; Appendix C).

The comparison between benefits associated to conventional farming and ecological almond cultivation identified conventional farming as providing the higher economic profit, while the ecological almond tree cultivation was mainly linked to a higher quality production (i.e. bigger

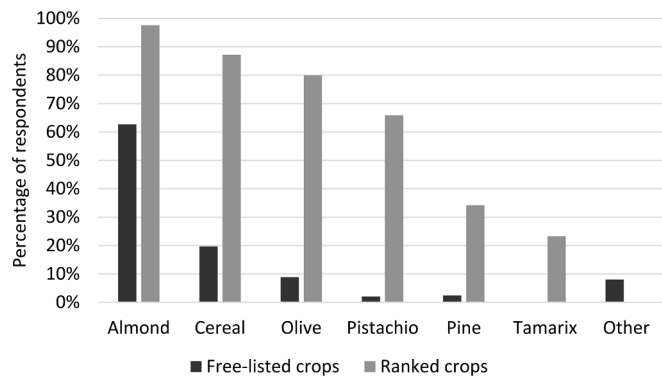


Fig. 2. Comparison between free-listed and ranked crops present in the study area.

size of almond) and a more environmental awareness behaviour (i.e. more sustainable over time) (Fig. 3).

3.2. Perceived awareness of ecosystem services

Out of 249 respondents in the pre-restoration phase, 45% responded that the study area "provides benefits to the well-being of local communities". This percentage increased to 95% after the post-restoration phase. In terms of the identified ES, in both pre- and post-restoration phases, most of the benefits identified were associated with provisioning ES, especially food production. However, we found that in the post-restoration, the number of cultural and regulating ES identified increased (i.e., from one to five for cultural ES and from three to six for regulating ES), including examples such as air purification, climate regulation, pollination, local identity, aesthetic appreciation (Fig. 4). Supplementary material summarizes full description of ES identified in pre and post restoration (Figure S1 and Table S1; Appendix C).

3.3. Social importance and trend of ecosystem services before and after almond restoration

Overall, provisioning ES (41%) were considered as the most important followed by regulating (32%) and cultural ES (26%). Specifically, the only ES identified as very important before and after the restoration was food production, with a mean importance of 2.42 (pre-restoration) and 2.20 (post-restoration) (Fig. 5). However, we found that freshwater supply was perceived as less important during the post restoration (with

a mean importance of 0.5). Most of the regulating ES increased in terms of social importance, specially erosion control and pollination (Fig. 5). Cultural ES were mostly ranked as less important in both the pre- and post-restoration. Further details regarding changes in ES importance between pre- and post-phases provided in see supplementary material (Figure S2; Appendix C).

Out of the 15 ES analysed, freshwater supply, pollination, water regulation, air purification, climate regulation, and erosion control were identified during the pre-restoration as the most vulnerable ES. Additionally, more than 60% of respondents considered that the supply of these ES had decreased in the last 10 years. This trend continued in the post-restoration phase, where erosion control was only identified with an increasing trend (60% of respondents). Overall, cultural ES were identified as the least important for both pre- and post-restoration, and with a stable or increasing trend. (Fig. 6).

3.4. Linkages between ecosystem service importance and vulnerability

For both stages of restoration, food production, pollination, climate regulation, and erosion control were characterized as critical ES (i.e., important and vulnerable). However, in the post-restoration phase, freshwater provision was classified as a vulnerable but not important (Fig. 5). In the vulnerable but not important category (Fig. 7), we observed a change in air purification, which was not identified in this category in the post-restoration phase, while fresh water supply became part of it. In the category of less relevant ES, we observe a dominance of cultural services in both phases (Fig. 7). Finally, in the important but not vulnerable category, we only observed the change in tourism, which is not identified in this category in the post-restoration stage.

3.5. Socio-demographic factors influence on ecosystem service perceptions

Perceptions for ES categories varied significantly amongst respondents according to their age, place of residence (region residents versus residents from other municipalities), rural development job (yes or not) and ownership of agricultural land (Lease, Ownership and none). People under 40 years of age recognized more regulating and cultural ES than those over 40. Residents of Los Vélez region perceived fewer regulating ES than residents from other municipalities, and respondents who do not own land mostly identified cultural ES. People working on rural development jobs recognized more cultural ES than people with other types of jobs, who, in turn, identified more regulating ES (Table 2). Although provisioning ES were the most appreciated ES by all respondents, no significant differences in ES perception were identified in

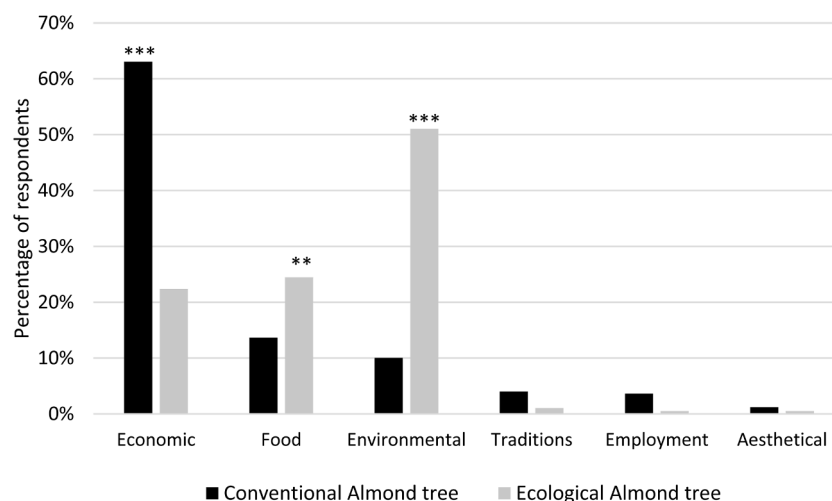


Fig. 3. Benefits associated to conventional almond tree farming versus ecological almond tree farming (** and *** indicate statistical significance, between benefits, at the 0.01 and 0.001 levels, respectively).

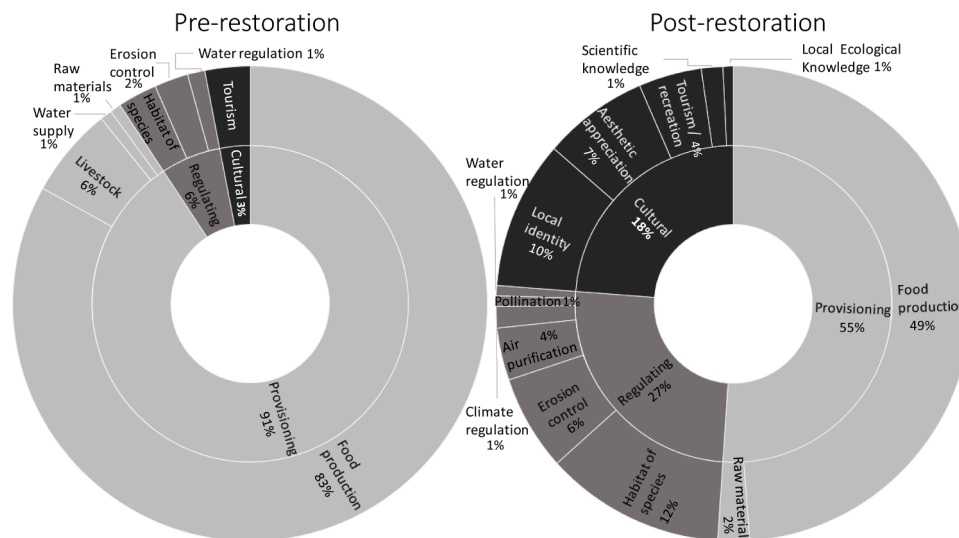


Fig. 4. Perceived awareness of ES during pre and post restoration. Classified by ES categories (provisioning, regulating and cultural).

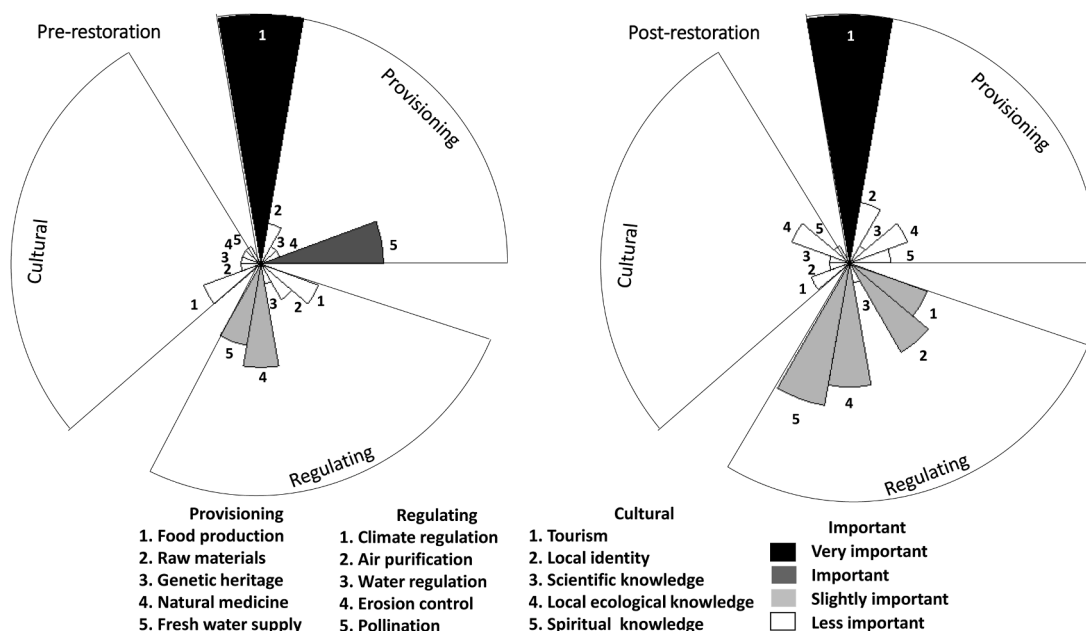


Fig. 5. Social preferences for ecosystem services in pre and post restoration. The bars represent the average importance value assigned to each ecosystem service.

any of the socio-demographic factors (Table 2).

3.6. Relationships between ecosystem service and human well-being

We found that preferences for ES were associated with their ability to support different components of human well-being (Fig. 8). Provisioning ES were most strongly related to "basic materials for a good life", specifically access to goods in the pre-restoration and the ability to have sufficient nutritious food in the post-restoration. Regulating ES were mainly linked to the security component (mainly providing safe access to resources), followed by basic materials for a good life and health. Finally, cultural ES were related to good social relations. We found that in each restoration stages the health component was indirectly connected to all ES categories (Fig. 8). Figure S2 of Appendix C summarizes linkages between ES categories and human well-being components.

4. Discussion

4.1. Changes in quantity and diversity of ecosystem services due to almond farming restoration

The socio-economic evaluation of ES gained through an almond tree restoration identified indicators that can help to enhance natural capital and people well-being. We specifically found changes in people's perceptions and concerns regarding the variety of ES and their impacts on natural capital and wellbeing. First, the number and diversity of ES increased significantly due to the restoration with almond trees, going from a single ES (i.e., 90% only identified food production) to the identification of 13 ES that included both cultural and regulating ES, (an increase of 27% and 18% of respondents, respectively). This result reflects that almond cultivation is not only perceived as an opportunity to increase food production (provisioning services), but also other cultural benefits (i.e., sense of belonging) and benefits associated with ecosystem processes (i.e., soil fertility) (Pérez-Ramírez et al., 2019). Additionally,

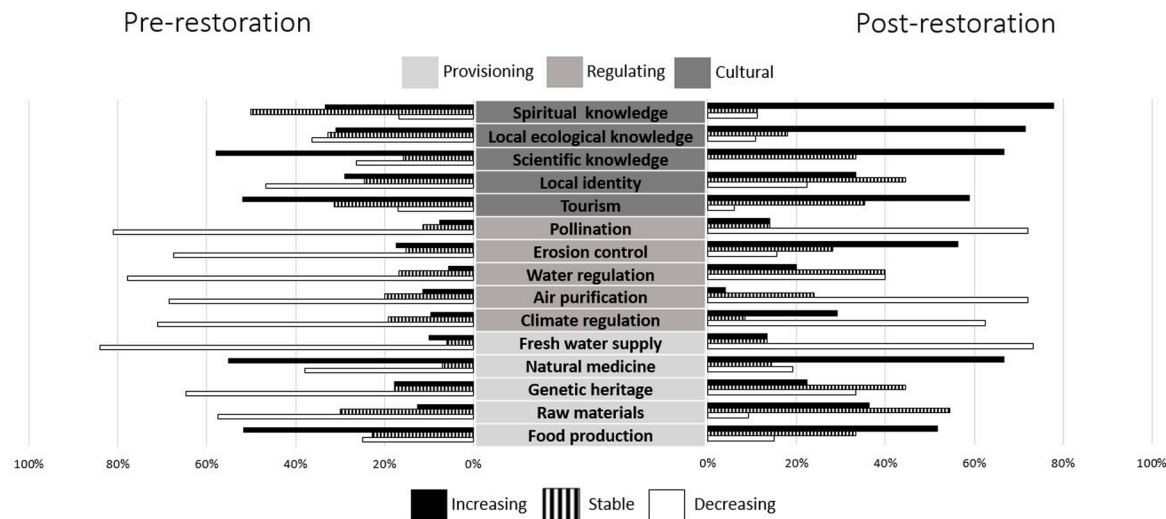


Fig. 6. Perceived trends of ES (i.e., decreasing, increasing, or stable) over the last ten years in pre- and post-restoration. Classified by ecosystem service categories (provisioning, regulating and cultural).

we also identified an increase in the social concern regarding those benefits classified as critical (e.g., pollination and air purification). This may reflect local stakeholders' understanding of the dependency relationships between provisioning ES and the regulating ES that support those (Narducci et al., 2019). On the other hand, we found that preferences for ES are conditioned by the socio-demographic characteristics, such as age, place of residence, rural development job, and owning land. This result is consistent with previous research (Quintas-Soriano et al., 2019), where visitors are more aware than residents regarding the importance of benefits linked to regulating ES, and working people in rural areas more broadly recognized the variety of benefits associated to cultural ES than those holding other types of jobs. This is consistent with previous studies carried out in the province of Almería, where the social perception of ES has been evaluated (Castro et al., 2011; 2018a, b; Quintas-Soriano et al., 2018b).

4.2. Ecosystem services as social indicators of human well-being

Recent research highlights the need to carry out studies that apply the ES framework to evaluate the social benefits of ecological restoration and biodiversity conservation strategies (Bullock et al., 2011; Martin et al., 2018; Castro et al., 2018b). In this sense, identifying the social benefits that local communities obtain and perceive is crucial to maintaining their commitment, trust, support throughout the process (Quintas-Soriano et al., 2018b). Thus, monitoring the maintenance of such benefits can enhance the success of ecosystem restoration by increasing the willingness of stakeholders to promote actions that will achieve long-term sustainability of the restored system (Martin and Lyons, 2018). Our results demonstrate that attempting to restore ecosystems and their biodiversity of a degraded ecosystem without considering people values, perceptions and interests can generate failures in both the process and final result (Rosa et al., 2020). The socio-economic evaluation of ES provides a practical approach for identifying social indicators that link ecological and social outcomes of ecosystem restoration (Rosa et al., 2020; Castro et al., 2011). Our results indicated that the diversity of ES identified increased considerably when the restoration ended, leading to changes in the values placed on specific ES (e.g. regulating ES were mostly perceived as critical), and facilitating the understanding of the role of ES in supporting human well-being, such as the contribution of cultural ES to social cohesion. The increased perception of regulating ES (i.e. pollination, water regulation or erosion control), may be influenced by a visible improvement in landscape connectivity, one of the main benefits of ecosystem

restoration (Peh et al., 2014). This finding reveals a possible direct relationship between ecological connectivity, ES provision and social awareness (Mitchell et al., 2013), and demonstrate that restoration monitoring schemes can be improved and complemented with socio-cultural assessments. Ecosystem restoration is increasingly used as a key tool in climate change adaptation and mitigation strategies, especially in vulnerable Mediterranean ecosystems (Harris et al., 2006; Wu et al., 2021). Further studies should analyse its potential use as a tool for improving and monitoring ecological connectivity. Additionally, moving from local to regional and national scale can determine if natural capital and the ecosystem service flow has been re-established in a given biome or ecosystem as a result of restoration actions.

Additionally, these findings fit within the strategies for meeting the aspirations of the UN Decade for Ecosystem Restoration 2021–2030 (United Nations Environment Agency 2019). More specifically, our results can be used for strategy six of such initiative, which seeks to study and inform the links between restoring ecosystem health and improving the health of human populations (i.e. physical, mental, social, and cultural), both locally and globally (Aronson et al., 2020). This study is one of the few that carry out analyses of how ecosystem restoration positively impacts not only ecosystem health but also enhance human wellbeing.

Despite the multiple advantages mentioned above, few studies have analysed the social perception of ES in the context of ecosystem restoration using the methodologies described here. amongst them are those carried out in Arizona and Colorado (United States), in which an attempt was made to determine whether the places socially valued at the aesthetic, life-supporting, cultural, economic, historical, intrinsic and biological diversity levels, amongst others, are significantly related to biophysical models of ecological restoration. They are or are not related to the biophysical provision of ES of areas with restoration or conservation potential. Identifying that life-supporting, local biodiversity and aesthetic values are the most important social values recognised by the population. The main tools used were surveys and SolVES (Social Values for Ecosystem Services) software (Bagstad et al., 2015; Petrakis et al., 2020). As in our study, they found a certain degree of social approval of restoration projects and identified the need to incorporate social values into landscape restoration investment decision-making.

4.3. Restoring agroecosystems to move towards a circular economy

With the resurgence of almond farming in Spain during the 1970s, the Los Vélez region began its transformation from traditional



Fig. 7. Scatter-plots classifying ES according to social importance (X-axes) and vulnerability (Y-axes) in (A) pre restoration, and (B) post restoration.

agriculture dominated by cereals to a monoculture of conventional non-irrigated almond trees (Navarro-López et al., 2012). By 2015, the Los Vélez region had 18,450 hectares of almond trees, 98.8% of which were non-irrigated and only 1.2% irrigated (Cosejería de Agricultura, Pesca y Desarrollo Rural, 2016). This production system transformation generated higher economic benefits for the population and produced changes at an ecological and landscape level (Govers et al., 2006). Some socio-cultural aspects started to revolve around almond farming and the activities derived from it (e.g. agro-tourism, raw material processing, educational programmes) (Navarro-López et al., 2012). In recent decades, the introduction of ecological almond tree varieties, denominated as such because of their characteristics such as late flowering, which make them more resistant to frost, lower water requirements and high productivity, has allowed the region to establish itself in new markets, becoming one of the areas with the highest production of ecological almonds in Spain (Cosejería de, 2016). Furthermore, these almond tree

varieties have obtained prices double those of conventional almonds, and in the last year, are the only almond variety not to have shown a downward price trend (ASAJA, 2020). When we ask our respondents about the benefits of conventional and ecological almond crops, we can see that they perceive greater economic benefits in conventional almonds crops, a view contrary to what the economic reports demonstrate (ASAJA, 2020). Reasons for this perception of some farmers may be that changing their crop from conventional to ecological would imply a significant cost with no short term return on investment, since almond trees require at least five years before they start to produce, a time period that increases when the crop is grown in dryland conditions. On the other hand, our respondents were able to perceive other benefits of ecological almond tree crops, such as higher fruit quality, resistance to pests, lower water requirements and greater integration with other productive activities such as livestock farming. According to the literature, ecological almond varieties, characterised by late flowering, are

Table 2

Socio-demographic factors influencing people's perception of ES. Asterisks indicate significant differences between categories, after the Kruskal-Wallis and the Mann-Whitney-U tests (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$) (SD: standard deviation).

Socio-economic factors	Categories	N	Mean (SD) Provisioning	Regulating	Cultural
Gender	Female	135	0.90 (0.41)	0.15 (0.43)	0.10 (0.33)
	Male	215	0.87 (0.44)	0.14 (0.41)	0.08 (0.27)
	U		14,134.5	14,535.5	14,254.0
Age	<40	174	0.84 (0.48)	0.19 (0.46)	0.13 (0.35)
	>40	172	0.92 (0.36)	0.10 (0.37)	0.05 (0.22)
	U		13,782	13,795*	13,936.5*
Place of residence	Los Vélez Region	259	0.89 (0.41)	0.12 (0.41)	0.07 (0.28)
	Others municipalities	91	0.86 (0.48)	0.21 (0.43)	0.13 (0.34)
	U		114,065	12,963.5*	12,513.5
Rural development job	Yes	168	0.86 (0.41)	0.11 (0.39)	0.13 (0.35)
	No	182	0.90 (0.45)	0.18 (0.43)	0.05 (0.22)
	U		15,876	16,494.5*	14,128.5*
Land ownership	Lease	19	0.79 (0.41)	0.16 (0.49)	0.00
	Ownership	171	0.89 (0.41)	0.13 (0.40)	0.02 (0.15)
	None	160	0.88 (0.46)	0.16 (0.43)	0.17 (0.39)
	X ²		1.06	0.80	22.26***
Educational level	University	129	0.95 (0.34)	0.13 (0.24)	0.11 (0.19)
	Professional formation	54	0.80 (0.45)	0.13 (0.44)	0.11 (0.38)
	High school	43	0.93 (0.33)	0.26 (0.57)	0.05 (0.21)
	Secondary school	57	0.79 (0.40)	0.14 (0.43)	0.12 (0.31)
	Primary school	51	0.86 (0.47)	0.06 (0.36)	0.04 (0.31)
	Others	16	0.88 (0.48)	0.31 (0.58)	0.00
	X ²		7.78	6.86	5.33

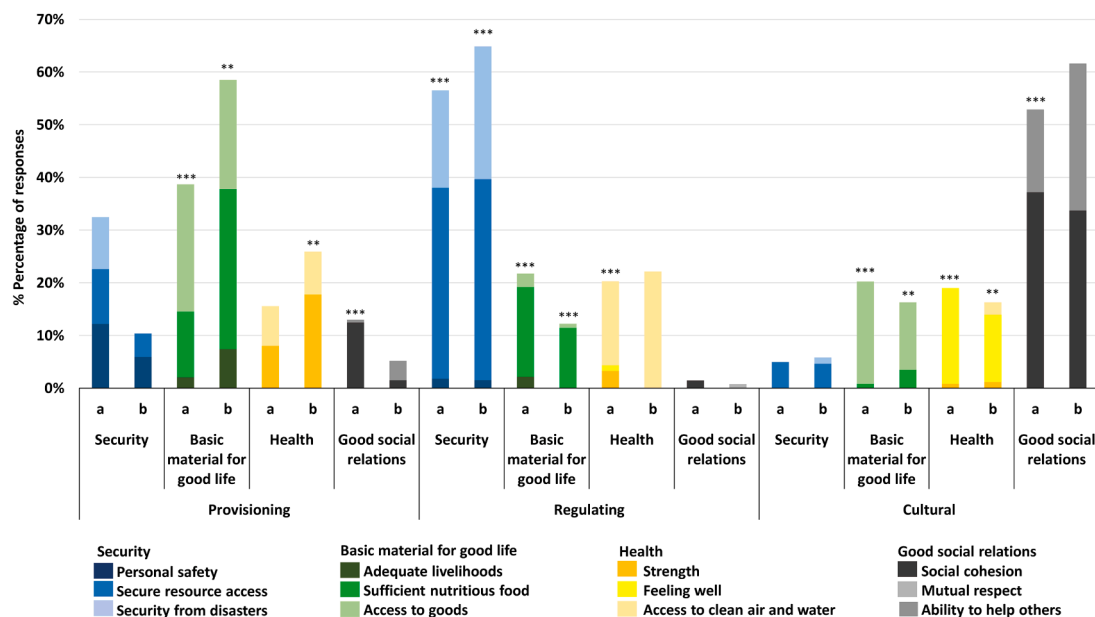


Fig. 8. Linkages between ES and components of human well-being in (a) pre-restoration and (b) post-restoration. Each colour group represents a human well-being component: 1. Security (Blue); 2. Basic material for good life (Green); 3. Health (Yellow); 4. Good social relations (Grey) (*** and ** indicate statistical significance, between human wellbeing sub-components, at the 0.001 and 0.01 levels, respectively).

less vulnerable to frost damage while maintaining their production (Sánchez-Pérez et al., 2014; Prudencio et al., 2018), and some studies have reported a higher amount of fatty acids in the almond kernels of these crop varieties (Piscopo et al., 2010). This evidences that social and environmental benefits are also important for local people and highlight the need to value all benefits, not only from a monetary perspective, that may arise in agroecosystems, but also from the quality of life and wellbeing perspective.

If we integrate the above observation into the CE framework, we note that the Los Vélez region's agro-system applies some CE operational principles, as defined by Suárez-Eiroa et al. (2019). The first of these is to adjust inputs to regeneration rates; this principle refers to minimising inputs of non-renewable resources and controlling the rates of

renewable resources. In this case, the mostly non-irrigated crops have low water requirements during production and, on land where livestock activities are also carried out, animal excrement serves as fertiliser for the almond trees. Secondly, the principle of adjusting the outputs of the system to the absorption rates refers to the need to minimise waste outputs and manage them in such a way that they become the raw material for another production process (Suárez-Eiroa et al., 2019; Elia et al., 2017). In the case of the almond tree, given that it is a plantation with an average useful life of around 20 years, the amount of organic material waste it can generate is low if we compare it to the intensive greenhouse horticulture that takes place in the province's south (Velázquez-Martí et al., 2012; Reinoso et al., 2019). In summary, the Los Velez region is a clear example of how agricultural systems can be

transformed and move towards sustainability, encompassing a wide range of benefits beyond the monetary, such as the maintenance of ecosystem functions, the provision of ecosystem services and social cohesion.

4.4. Is almond farming stable in Spain?

If we analyse the agroecosystem of almond farming on a larger scale, we find that Spain is the country with the largest cultivated area of almond trees in the world, with more than 700,000 ha (MAPA, Ministerio de Agricultura, Pesca y Alimentación 2018). However, it ranks third in terms of production because most of the cultivated area is not irrigated and with a low density of trees per hectare. amongst the countries ahead of Spain is Australia, in second place, with more than 53,000 hectares under almond trees plantations and an annual production of around 120,000 tonnes (USDA, United States Department of Agriculture - National Agricultural Statistics Service 2020a). In first place is the United States, with more than 500,000 ha planted with almond trees and more than one million tonnes in annual production (USDA, United States Department of Agriculture - National Agricultural Statistics Service 2020b). Its agricultural system, as in Australia, is intensive with full irrigation to maximise productivity (Goldhamer and Fereres, 2017).

However, during the last decade in Spain, there has been an increase in intensive almond tree plantations characterised by the use of irrigation, fertilisers, new varieties of almond trees and a higher density of trees per hectare (MAPA, Ministerio de Agricultura, Pesca y Alimentación 2018). This intensive agricultural system in a context where the share of irrigation water is limited, both in terms of availability and in terms of institutional regulations may not be sustainable in the medium and long term, depending on water availability, access and water use policy. Different studies have tried to determine what the future of these plantations will be like, with water as a limiting factor, by simulating deficit irrigation systems and comparing crop productivity (Expósito et al., 2020; Moldero et al., 2021). Their results suggest that the productive capacity of the trees is maintained even with severe deficit irrigation systems, so that total irrigation systems, such as those used in Australia and the USA, may not be necessary (Expósito and Berbel, 2020; Moldero et al., 2021). In these countries, water governance is currently undergoing radical change in response to the severe impacts of recent droughts, and in California, this situation has prompted the creation of a new Sustainable Groundwater Management Act (Berbel and Esteban, 2019).

4.5. Moving beyond economic valuation of farming systems

Economic assessments of sustainable almond production, in any context, tend to be limited to crop yields disregarding management costs and externalities. Crop yield, however, is not a comprehensive indicator of farm economic benefits. Market price, labour, operational and input costs, investment costs, as well as investment costs and subsidies also have a significant influence on farm profitability (Jezeer et al., 2018; Sgroi et al., 2015). In the case of restoration with almond production (De Leijster et al., 2020), we found that ES can contribute to a better farm economic resilience in the long-term; however, empirical evidence is scarce. Much depends on the extent to which externalities are addressed by private and public incentives. For example, price premiums (e.g. coupled to certification schemes) or green incentives under programs such as the Common Agricultural Policy affect the economic sustainability of the agricultural activity. Water footprint certifications can be one method to add value to agricultural products. Sánchez-Bravo et al. (2020) researched consumer perception of how to save water in the food chain and how to identify water sustainable products by a logo, in Brazil, China, India, Mexico, Spain and the USA. The logo was positively rated by consumers, especially by young generations, although it is evident that consumers have significant knowledge gaps about water use

in food production and processing in general.

Finally, economic assessments are also dependant not only on the “rules of the game” which determine the market and the perception of added value by consumers. The methodologies used to calculate positive benefit depend as well on the number and type of externalities internalised and over which period. It is evident that sustainable water practices will depend on the extent to which public policy adopts an economics of biodiversity that includes socio-ecological details and an accounting that includes natural capital, as well as consumer perception of the added value and willingness to pay for natural capital and biodiversity.

5. - Conclusion

The UN Decade on Ecosystem Restoration is a rallying call for the preservation and revival of ecosystems all around the world, for the benefit of both people and nature. This paper implements the ES framework to tie together the concepts of agricultural activity and ecosystem restoration within the circular economy. Specifically, we propose a method for devising social indicators of ecosystem restoration that may be taken into account in processes of transition towards more circular and sustainable economic systems. We call the need of integrating social indicators of ecosystem restoration in policies and initiatives for successfully transition to circular economy, and to achieve challenges of the UN Decade on Ecosystem Restoration.

CRedit Author Statement

Daniela Alba-Patiño: Formal analysis; Investigation; Writing–Original draft preparation. **Vicenç Carabassa:** Methodology; Project administration. **Hermelindo Castro:** Project administration; Funding acquisition. **Inés Gutiérrez-Briceno:** Data curation; Investigation. **Marina García-Llorente:** Conceptualization; Methodology; Validation. **Cynthia Giagnocavo:** Resources; Writing–Original draft preparation. **Miguel Gómez-Tenorio:** Project administration and Resources. **José A. Aznar-Sánchez:** Resources; Conceptualization. **Antonio J. Castro:** Conceptualization; Methodology; Writing–Original draft preparation; Supervision.

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.

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Supplementary materials

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