A comprehensive approach for agroecosystem services and disservices valuation

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ABSTRACT

The use of the ecosystem services approach for ecosystem management, including the valuation of ecosystem services, has grown in recent decades. Although a common framework is used, each ecosystem has its own characteristics. The agroecosystem, for example, is an anthropised ecosystem where ecosystem service flows are highly interrelated with the environment, positively or negatively. Therefore, agroecosystem services are usually accompanied by disservices. The valuation of agroecosystem services and disservices requires adaptation of existing ecosystem services paradigms to accommodate the innate agroecosystem idiosyncrasies. To this end, in this study, a comprehensive approach for valuation of agroecosystem services and disservices was proposed and validated in a semi-arid western Mediterranean agricultural area through stakeholder assessment, using a choice experiment. The results suggest that all categories of services (provisioning, regulating, and cultural) should be taken into account when valuing agroecosystem services and disservices. In particular, food provision (a provisioning service), water (a provisioning disservice), local climate regulation and biodiversity (regulating services), waste treatment and water purification (regulating disservices), and recreation and tourism (cultural services) are relevant for this purpose. Their relative importance in agroecosystems valuation reached 70% for agroecosystem services and 30% for disservices. Specifically, biodiversity (38%) emerged as the most relevant agroecosystem service to be valued, followed by recreation and tourism (20%), local climate regulation (7%), and food provision (5%). Among the agroecosystem disservices, water and waste treatment (15%), and water purification (15%) together contributed to 30% of the total importance. Agroecosystems should be valued considering their multifunctional character and the integration of agroecosystem services and disservices.

Keywords: Anthropised ecosystems; Choice experiment; Mediterranean agroecosystems; Stakeholder assessment; Human well-being.

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1. INTRODUCTION

The ecosystem services approach highlights the importance of nature's contribution to human life and well-being. The notion of ecosystem services reveals that human well-being closely depends on the ecosystems in which humans exist. Ecosystem functioning impacts human well-being through the ecosystem services provided. Ecosystems may supply food, fuel, or fibre (provisioning services), contribute to the regulation of natural functions (regulating services), or even provide an environment for leisure activities (cultural services). Thus, ecosystem services represent ecosystem flows that are ultimately perceived as contributions to human well-being.

Over the past two decades, both development and extension of the ecosystem services approach have been encouraged through growth of the related literature and international institutional support. From *"the benefits people obtain from ecosystems"* (MEA, 2005) to *"the contributions that ecosystems make to human wellbeing"* (Haines-Young and Potschin, 2018), the definition of ecosystem services in the scientific literature has been adapted over time to incorporate the advances achieved. Initiatives such as MEA (2005), TEEB (2010), FEGS-CS (Landers and Nahlik, 2013), IPBES (Pascual et al., 2017), and CICES (Haines-Young and Potschin, 2018) reflect this development process. Most of these initiatives have served to establish a solid theoretical basis for the definition and classification of ecosystem services and the impact of ecosystems on human well-being (Costanza et al., 2017). However, despite their wide use and extension, these definitions and classifications may not fit all types of ecosystems (Fisher et al., 2009; Ojea et al., 2012). The different ecosystem services frameworks developed assume that ecosystem service flows arise from natural processes and no human interactions are considered within the ecosystem functions. However, many ecosystems have been deeply transformed by humans, in such a way that their functioning has, in many cases, totally changed (Palomo et al., 2016). As ecosystem functions are influenced by human activities, it ultimately affects the provision of ecosystem services (Lele et al., 2013). Therefore, in anthropised ecosystems, such as agroecosystems, the flow of services should be carefully considered (Barot et al., 2017).

Agroecosystems are created by humans to provide a specific provisioning service. This involves such a degree of anthropisation that human activities, mainly through agricultural practices, affect the innate functioning of these ecosystems. Therefore, agroecosystem services are not fully produced by agroecosystem functioning, and their provision is determined by the level of human activity within each agroecosystem (Mach et al., 2015). Agroecosystem services are, therefore, co-produced by both the natural ecosystem and the human hand (Fischer and Eastwood, 2016).

[1] *Abbreviations and acronyms.* AES: Agroecosystem services; AEDS: Agroecosystem disservices; IIA: Independence of irrelevant alternatives.

In addition, this human interference may not always have the desired positive outcomes (Barot et al., 2017). First, agricultural practices may impact the current state of agroecosystems, negatively affecting their capacity to provide agroecosystem services (AES). Second, they can also lead to the provision of agroecosystem disservices (AEDS), which are defined as the "generated functions, processes and attributes that result in perceived or actual negative impacts on human wellbeing" (Shackleton et al., 2016), revealing that agroecosystem contributions can also be harmful. Furthermore, interrelationships between AES and AEDS are expected in agroecosystems, providing many more trade-offs among them than win-win solutions. In turn, these trade-offs are promoted by human practices, which add complexity to the assessment of agroecosystems (Tancoigne et al., 2014).

The expression of the value of AES and AEDS serves to raise awareness of the overall importance of agroecosystems to society and policy makers (De Groot et al., 2012). Both AES and AEDS are valued as long as they provide benefits and costs, respectively, to socioeconomic systems. Benefits and costs may be economic, environmental, or social, and are derived from the direct and indirect use of AES and AEDS, from the option of using them in the future (option value) or even from the mere knowledge of their existence (non-use value) (Pearce and Turner, 1990). In addition, these values are context-dependent (Díaz et al., 2018). Time, spatial scale, cultural background, and stakeholder involvement are key elements that determine the values of AES and AEDS received by a socioeconomic system. It is well known that agroecosystems provide benefits and costs to society, but there is no consensus in the literature regarding the main AES and AEDS that should be valued. In fact, recent advances in AES valuation refer to specific AES without a common agreement. Rodríguez-Entrena et al. (2014) and Granado-Díaz et al. (2020) focused on the economic valuation of erosion control, carbon sequestration, and biodiversity in olive agroecosystems in Andalusia (southern Spain); Divinsky et al. (2017) valued food provision, pollination, and landscape on an experimental farm in Galilee (NE Israel); and Bernués et al. (2019) assessed the social demand for quality food products, fire control, biodiversity, and landscape in mountain agroecosystems in Huesca (NE Spain).

In this context, this study aimed to identify the AES and AEDS that should be valued, considering the innate idiosyncrasies of agroecosystems. To this end, a comprehensive agroecosystem assessment approach was proposed and validated using a stakeholder choice experiment. The Region of Murcia (south-eastern Spain) was used as a case study because it is representative of semi-arid western Mediterranean agroecosystems.

The novelty of this research lies in its integration of anthropisation, AES, and AEDS into a common approach for agroecosystem valuation, while it also considers the overall complex relationships between the biophysical and socioeconomic systems. Therefore, this study aids in filling the knowledge gap regarding the integrated valuation of AES and AEDS, and its implications are expected to be useful for research purposes and decision-making. First, the proposed framework enables the adaptation of the main ecosystem services paradigms to the specifics of agroecosystems. Second, the results of a stakeholder assessment elucidate the relative relevance of the AES and AEDS valued in a semi-arid western Mediterranean context. Thus, this study provides researchers with baseline information to value the overall contributions of agroecosystems to human well-being. It also provides policy makers with background information that should enable them to focus on the AES and AEDS that need to be better managed.

In the following section of this paper, a comprehensive approach for agroecosystem assessment is proposed. Sections 3 and 4 describe the validation of this approach through a stakeholder choice experiment, including the methodology used and the results, respectively. In Section 5, the results and their implications are discussed and Section 6 is the conclusion of the paper.

2. A COMPREHENSIVE AGROECOSYSTEM ASSESSMENT APPROACH

In an anthropised ecosystem, the integrated valuation of AES and AEDS requires a framework that considers both positive and negative impacts on human well-being. To achieve this, the Barot et al. (2017) framework for anthropised ecosystems has been applied. In addition, the main paradigms for ecosystem services, such as MEA (2005), TEEB (2010), and CICES (Haines-Young and Potschin, 2018), have been revised and readapted to the innate idiosyncrasies of the agroecosystem. Barot et al. (2017) adapted the *Capacity, Flow, Demand, and Pressure* framework developed by Villamagma et al. (2013) to include anthropisation and the presence of disservices within a common framework. This framework assumes that agroecosystem functioning depends on the state of health of the agroecosystem as well as on the biodiversity and the innate processes and functions within the agroecosystem (Figure 1). Agroecosystem functioning comprises the agroecosystem functions that form the basis of production of AES and AEDS flows. The joint consideration of agroecosystem state, biodiversity, and functioning determines the potential of an agroecosystem to provide AES and AEDS, namely, the agroecosystem capacity. Agroecosystem functioning impacts human well-being by means of the AES and AEDS provided, which are therefore considered the flows from the agroecosystem to the socioeconomic system. However, within the socioeconomic system, AES and AEDS represent benefits and costs, respectively, which could be translated into economic values by means of market and non-market valuation methods.

At this point, it should be stated that the benefits and costs related to AES and AEDS are not fixed over space and time but depend on the context in which they are framed (Díaz et al., 2018). The demand for AES and AEDS, that is, the amount of services and disservices desired, is determined by the entire society, and consequently by sociocultural preferences. Preferences, which are assumed to be invariant in a specific context (Braga and Starmer, 2005), are ascertained by both the concrete agroecosystem and the sociocultural frame within which they are evaluated (Bernués et al., 2019; Alcon et al., 2020b). Consequently, stakeholders also play a key role in creating demand within the socioeconomic system. Their actions may have an influence not only on the value that AES and AEDS provide, but also, and mainly, on the way an agroecosystem is managed. This management will in turn affect the functioning of the agroecosystem and thus its capacity to generate AES and AEDS flows. Agricultural practices represent the main human pressure on an agroecosystem.

The proposed approach seeks to capture the innate idiosyncrasies of agroecosystems. Trade-offs between AES and AEDS are expected within an agroecosystem, and are influenced by pressures (Barot et al., 2017). For instance, food provision, which is the core service provided by agroecosystems, can be enhanced by agricultural practices (pressures), such as fertiliser application, but this may imply the emission of contaminants to the atmosphere and water bodies, thus providing AEDS. Consequently, not only the capacity of the agroecosystem could be affected, but also its functioning, which ultimately affects the current AES and AEDS flows. Furthermore, trade-offs and pressures reduce the capacity of an agroecosystem to provide the maximum level of AES. Human demand also influences the capacity and functioning of an agroecosystem through pressures; therefore, the provision of AES and AEDS is a consequence of the relationship between humans and nature. A final point to note is that this approach focusses only on the agroecosystem, without considering connections between it and surrounding ecosystems beyond the AES and AEDS provided. Consequently, land use changes, which may imply transition from or to other ecosystem types (e.g. from forest to agroecosystems) are not considered.

Figure 1. About here.

Our approach encompasses two different but interrelated systems: the biophysical system, which corresponds to the agroecosystem, and the socioeconomic system, centred on human well-being (Figure 1). In the biophysical system, the proposed approach can also be translated to the existing typologies of ecosystem services. In the socioeconomic system, AES and AEDS are treated as benefits and costs, respectively, according to their impact on human well-being. Table 1 summarises how the most widely applied ecosystem services paradigms are connected as well as how they were readapted to the specific case of the agroecosystem. For this purpose, a chronological order was followed from MEA (2005) to CICES (Haines-Young and Potschin, 2018).

Regarding provisioning services, the main classifications agree on and recognise different types of ecosystem services, not just food provision. However, when the agroecosystem is considered, food provision could be assessed as one of the AES, and water as one of the AEDS. Of the AES, food is the only one considered in the assessment of agroecosystems because the other ecosystem services all translate into production outputs. In the case of water ecosystem services, however, agroecosystems do not provide fresh water to other ecosystems, but instead utilise water from them, consequently decreasing the availability of water in these other ecosystems (Strzepek and Boehlert, 2010). Water demand for agricultural purposes has become a pressure for freshwater ecosystems. Environmental flows (e-flows) might be therefore undermined by agroecosystem functioning, which in turn could be translated into a depletion of water ecosystem services and may compromise the sustainability and well-being of organisms that depend on these ecosystems (Kuriqi et al., 2019, 2020; Zheng et al., 2020). For such reasons, agroecosystems provide water AEDS rather than water AES.

Regulating services represent the widest category of agroecosystem services. Our approach also includes some supporting services, in the case of MEA (2005), and habitat services, in the case of TEEB (2010); specifically, only those services that would not imply double-accounting bias. Regarding air quality regulation, all the classifications concur that ecosystems contribute positively to improvements in air quality, diminishing the contaminants of human origin. However, this is not the case for agriculture, which may be responsible for emitting contaminants to the atmosphere, such as ammonia or nitrous oxide, derived mainly from fertiliser application (Tubiello et al., 2015). Thus, the contribution of agroecosystems to air quality regulation is expected to be negative and should be considered as one of the AEDS. Climate regulation is broadly recognised as being among the AES in all classifications. The contribution of ecosystems to climate regulation can be considered both globally and locally because ecosystem functioning can impact the global carbon cycle dynamics as well as the thermodynamics and weather in the locations where the ecosystems exist. Therefore, an agroecosystem could contribute to carbon sequestration, both in the soil and by crop photosynthesis, which would form part of the agroecosystem contribution to global climate regulation (González-Sánchez et al., 2012). In addition, an agroecosystem could also contribute to temperature regulation, which is part of local climate regulation (Albaladejo-García et al., 2020).

Although water regulation is included within the main ecosystem services paradigms, it cannot be applied in the case of agroecosystems because the agroecosystem contribution to the regulation of water cycle dynamics is relatively insignificant compared to that of other ecosystems. In addition, water regulation, which includes evapotranspiration, infiltration, and runoff, is closely related to agroecosystem functioning, water supply, and water purification, generating service overlapping and double-counting biases when it is valued (Ojea et al., 2012). However, agroecosystems may interfere with water purification and waste treatment. Agricultural soils provide water purification, preventing the filtering of nutrients to aquatic ecosystems (Schröder et al., 2020). This agroecosystem function could also be enhanced by agricultural practices, such as cover crops (Skaalsveen et al., 2019) or the inclusion of buffer strips to delimit cropland (Terrado et al., 2015), thereby providing AES. In addition, other agricultural practices, especially fertiliser application, which have been considered as pressures in our approach, may be responsible for water pollution. The runoff and leaching of water following excessive use of nitrogen fertiliser generates diffuse pollution from agriculture, which contributes directly to the salinisation of groundwater and may negatively affect other ecosystems (Jiménez-Martínez et al., 2016), thereby providing AEDS.

Ecosystem functioning contributes to soil conservation and quality in different ways, including erosion prevention, soil formation, and soil fertility. The state of the soil is crucial to agroecosystem functioning, and agricultural practices may affect this. Therefore, the agricultural contribution to soil maintenance may be positive or negative depending on the management practices. Intensive tillage, quite common in traditional agriculture, may generate high erosion rates and, therefore, AEDS (Montgomery, 2007). However, more environment-friendly practices such as crop diversification or green manure use can boost soil organic matter, increase fertility, and thus contribute to soil maintenance (Morugán-Coronado et al., 2020), implying the provision of AES. Therefore, agroecosystems can contribute positively and negatively to soil, providing both AES and AEDS, respectively.

Biological control of diseases and pests, and pollination are considered in most ecosystem services classifications. However, the case of the agroecosystem is again quite different because agroecosystems receive biocontrol agents and pollinators from other ecosystems. As Zhang et al. (2007) and Power (2010) suggested that biological control and pollination are ecosystem services provided to an agroecosystem by natural habitats. These external services allow agroecosystems to maintain the provision of AES flows. Nevertheless, agricultural practices can also impact the provision level of biological control and pollination ecosystem services. Conservation agriculture and crop diversification are two examples of agricultural practices that have positive impacts on biological control and pollinators (Aguilera et al., 2020). Conversely, agricultural intensification, mainly through pesticide and fertiliser application, is responsible for the decrease in pollinators worldwide (Potts et al., 2010; Main et al., 2020) as well as for the loss of soil and plant biodiversity (Culman et al., 2010; Beeckman et al., 2018). Based on this, agriculture does affect the maintenance of genetic diversity within an agroecosystem, and therefore agroecosystems contribute to biodiversity (Paiola et al., 2020). Impacts on biodiversity could be both positive and negative depending on the particular agricultural practices. Therefore, agriculture may promote or reduce the biodiversity that develops within an agroecosystem (Martin et al., 2019), providing both AES and AEDS.

Agroecosystems may contribute to the regulation of extreme events, such as floods, by improving the resilience of ecosystems. Resilience, defined as the ability of systems (either ecosystems or socioeconomic systems) to maintain their original functioning and capability after exposure to a disruptive change (Holling, 1973), is key to ensuring the long-term sustainability of agroecosystems themselves, but, above all, of their surrounding ecosystems and socioeconomic systems. The capacity of agroecosystems to moderate extreme events, mainly through the capability of crops and vegetation to retain and store water, may mitigate the consequences of climate change, such as heavy rainfall, floods, and drought. Resilience, in this sense, should be understood not only as the moderation of extreme events, but also as a positive contribution to the human well-being derived from it (Qiu, 2019). The focus is on mitigating the negative effects that disruptive changes would produce in the absence of agroecosystems. Therefore, agroecosystems can mitigate the negative impacts of extreme events on surrounding ecosystems and socioeconomic systems, and thereby enhance the resilience of these systems. This enhanced resilience should also be considered as a service provided by agroecosystems (Peterson et al., 2018).

Cultural AES should also be included in the assessment of agroecosystems in order to add the non-material benefits that agroecosystems provide to society (Huber and Finger, 2019). These benefits could be obtained through spiritual and cultural values, aesthetic values, opportunities for recreation, tourism, and cognitive development. They fit completely with the main ecosystem services classifications.

Table 1. About here.

The socioeconomic system of the proposed approach (Figure 1) focusses on how AES and AEDS are perceived as benefits and costs, respectively. The interrelationships between the biophysical and socioeconomic systems show how provisioning, regulating, and cultural AES and AEDS are perceived as economic, environmental, and social benefits and costs, respectively, in the socioeconomic system, having an economic value. The economic value is derived from their direct and indirect use, the option of their use in the future, and even their mere existence (non-use value) (Pearce and Turner, 1990).

Table 2 shows the links between the proposed AES and AEDS and their respective type of benefit and cost, and their type of value (TEEB, 2010). Provisioning AES and AEDS are mostly related to economic benefits and costs, while regulating and cultural AES and AEDS are linked to environmental and social benefits and costs, respectively. However, these relationships are not always so straightforward. For instance, provisioning AEDS may also provide environmental costs, while cultural AES may generate economic benefits. Regarding value, provisioning AES and AEDS tend to be valued in relation to their direct use, regulating AES and AEDS are more related to indirect use and option values, and cultural AES and AEDS mostly refer to direct use, option, and non-use values.

Table 2. About here.

3. METHODOLOGY

3.1. Case study

This case study was located in the Region of Murcia (south-eastern Spain), within the Segura River Basin (Figure 2). This region is characterised by a semi-arid climate with low rainfall and long periods of drought which generate agri-environmental challenges such as water scarcity, groundwater overexploitation, salinisation, and biodiversity loss. Agriculture represents a relevant socioeconomic activity which accounts for more than 5% of the regional GDP (INE, 2018) and nearly 12% of the regional employment (INE, 2019).

The agroecosystems within the case study area are based on a dual system, where irrigated and rainfed agriculture coexist. The irrigated agroecosystems comprise 188,000 ha (CARM, 2019) of high-productivity fruit and horticultural crops (Alcon et al., 2017), and these, in turn, are divided into two agricultural subsystems: traditional and intensive. The Segura River valley hosts traditional irrigation (Heider et al., 2018), while intensive irrigation occurs further away from the river (Alcon et al., 2020a). The rainfed agroecosystem is distinguished by low profitability, with almonds the main crop. It covers approximately 253,000 ha (CARM, 2019), distributed throughout the case study area. It should be noted that some aquifers and a coastal ecosystem, the Mar Menor lagoon, are influenced by agricultural flows in the region. The agri-environmental and socioeconomic characteristics, as well as the blend of different and interdependent agroecosystems, make the Region of Murcia a representative case study for the semi-arid western Mediterranean area (Martínez-Paz et al., 2018).

Figure 2. About here.

3.2. Choice experiment method

The choice experiment is a stated preference method based on the multi-attribute utility theory (Lancaster, 1966) and the random utility theory (McFadden, 1974). Accordingly, an agroecosystem can be defined as a set of AES and AEDS, and individuals can choose the preferred agroecosystem alternative according to their expected utility level. Choice experiment applications in agri-environmental valuation tend to include a status quo (SQ) or opt-out alternative that reflects the current situation, where no action is taken (Barreiro-Hurle et al., 2018). In our case study, the SQ alternative was the rainfed agroecosystem, which is less human-managed than the irrigated agroecosystem.

The choice experiment method is appropriate for selecting the most relevant AES and AEDS for valuation, because it allows the modelling of individual discrete choices among different AES and AEDS, and even among different agroecosystems. It is important to note that a wide range of methods could be used to attain the research objective, including multi-criteria analysis and, more specifically, the analytic hierarchy process. However, these methods only allow us to consider all the AES and AEDS trade-offs through pairwise comparisons, and not in an integrated way, despite providing similar results (Kallas et al., 2011). The choice experiment method has been widely applied to AES valuation (Rodríguez-Entrena et al., 2014; Bernués et al., 2019), but has been slightly used for stakeholder assessment (Villanueva et al., 2017).

Developing and implementing a choice experiment involves a five-step process (Hoyos, 2010): (1) selection and definition of attributes and levels, (2) choice set design, (3) questionnaire development, (4) sampling strategy and data collection, and (5) assessment of choices and modelling of results. The first two steps are summarised in Section 3.2.1 (Experimental design). Questionnaire development is covered in Section 3.2.2 (Sampling and data collection). Section 3.2.3 describes how the assessment of choices and modelling of results was accomplished in relation to an econometric framework. Figure 3 shows a flowchart of the choice experiment development and implementation process.

Figure 3. About here.

3.2.1. Experimental design

The attributes included in the choice experiment design are associated with the relevant AES and AEDS identified in Section 2 (Table 3). The indicators for the attributes were selected following those proposed by Maes et al. (2016) and the van Oudenhoven et al. (2018) criteria. The selection of attribute levels was based on a review of available literature about the agroecosystems in the case study area (e.g. Alcon et al., 2017; Perni and Martínez-Paz, 2017; Albaladejo-García et al., 2020; Martin-Gorriz et al., 2020a), and focused on the specific indicators selected for the attributes. These attribute levels were chosen to cover the range of AES and AEDS of the three main agroecosystems included in the case study: rainfed, traditionally irrigated, and intensively irrigated. Hence, each level of every attribute represented a different agroecosystem in the case study. Levels were measured in physical or monetary units to improve the reliability of the experiment.

The attributes for the provisioning AES and AEDS were associated with the value of crop production (yield) and irrigation water use (water supply for irrigation). Economic yield was selected as an indicator to replace food supply, thereby homogenising different crop yields. The yield indicator levels were obtained from Alcon et al. (2017) and Lehtonen et al. (2020). Food provision can be easily evaluated as an AES since food can be exchanged in a market. However, the economic value of this AES goes beyond the market value of agricultural production because it comprises the contribution of agriculture to food security (option value).

Water management is a crucial issue within the case study area, not only for farmers and policy makers, but for the entire society due to competition for water among sectors (Perni and Martínez-Paz, 2017; Zabala et al., 2019). The selected indicator was therefore the amount of water employed directly for irrigation, and the levels were obtained from Alcon et al. (2017). This means that when fresh water, which serves as a limiting resource in water-scarce regions, is directly employed in agriculture, it is not available for alternative uses in other ecosystems. Thus, the greater the use of irrigation water, the greater the AEDS provided by the agroecosystems.

The attributes related to the regulating AES and AEDS were carbon balance, temperature regulation, groundwater pollution, erosion, bird richness, and resilience. Carbon balance is defined as the net uptake of greenhouse gases by agroecosystems, and its indicator summarises the difference between carbon sequestration by, and greenhouse gas emissions from the agroecosystems. Therefore, carbon balance represents both the AES related to global climate regulation and the AEDS related to the emission of contaminants into the atmosphere. Hence, positive values of this indicator are associated with regulation of AES. The levels of this attribute were obtained from carbon balance data for the main crops grown in the case study area, following Martin-Gorriz et al. (2020a, 2020b).

Another of the AES, climate regulation, was considered because it is influenced by agricultural practices (Almagro et al., 2016). Irrigated agriculture can reduce the local temperature (Albaladejo-García et al., 2020), and is, therefore, expected to have a positive impact on human well-being in semi-arid areas. Therefore, temperature regulation was included in the experimental design as an indicator for the local climate regulation AES. Attribute levels of local climate regulation were obtained from Albaladejo-García et al. (2020), who suggested that irrigated agroecosystems may reduce the land surface temperature by up to 2 °C compared to rainfed agroecosystems.

Groundwater pollution is a growing phenomenon in Mediterranean regions and is mainly caused by diffuse pollution from agriculture (Alcolea et al., 2019). It reveals how agroecosystems may negatively impact other ecosystems and represents the AEDS associated with water purification and waste treatment. The indicator used to measure groundwater pollution was the nitrate concentration in aquifers associated with each of the agroecosystems in the Region of Murcia (CHS, 2017).

Conventional agricultural practices, such as regular tillage and herbicide treatments, tend to erode soil (Montgomery, 2007). The negative contribution of agriculture to soil maintenance can, therefore, be seen as a disservice originating from agroecosystems, and annual erosion rates could be used as an indicator. However, given the great variety of erosion rates among agroecosystems, and even within each of the agroecosystems (García-Ruiz et al., 2013) included in the case study, this indicator was finally translated into a dummy variable which distinguished between high and low levels.

Contributions of the case study agroecosystems to biodiversity were measured as bird richness. Selection of this indicator was motivated by the fact that bird richness in the area had declined prior to this study as a consequence of agricultural activity (Palacín and Alonso, 2018; Martínez-López et al., 2019). In addition, bird richness is an easily understood indicator, as shown in several agroecosystem valuations (Rodríguez-Entrena et al., 2014; Varela et al., 2018). Biodiversity levels were defined as the share of the potential of bird richness that could be found in each of the agroecosystems, following the Perni and Martínez-Paz (2017) procedure. Bird species richness is known to be enhanced by crop diversity and heterogeneous landscapes (Stjernman et al., 2019), even in woody crops (Rime et al., 2020). Therefore, low intensity agroecosystems together with heterogeneous landscapes, such as the traditionally irrigated agroecosystem in the case study, were expected to provide greater bird species richness. Similarly, it was expected that the intensively irrigated agroecosystem, dominated by monoculture, would present a 60% bird richness level with respect to the potential, whereas for the rainfed agroecosystem, with low intensity agriculture and homogeneous landscapes, a value of 80% was expected. Although the contribution of agroecosystems to biodiversity is not always linear according to agricultural intensity (Beckmann et al., 2019), in this study it was assumed that the less intensive the agriculture, the greater the biodiversity the agroecosystem would hold, hence, the more resilient it would be (Augeraud-Véron et al., 2019). Consequently, rainfed and traditionally irrigated agroecosystems were assumed to be more resilient than the intensively irrigated ones. The final regulating attribute, resilience, was measured as the capacity of the agroecosystems to adapt to climate change. Given the difficulty of summarising this concept in just one measurable indicator (Cabell and Oelofse, 2012), it was included as a dummy variable based on whether the agroecosystem could adapt to climate change or not.

The cultural contribution of agroecosystems to human well-being was included in the experiment as four attributes. Agroecosystems contribute to the traditions and cultural identity of agricultural areas as well as providing landscapes for visual enjoyment and environments for leisure and recreational activities. The contribution to cognitive development and good living was included as the generation of local employment (Laterra et al., 2019). The capacity of each agroecosystem to generate employment was measured as the number of hours of labour needed to manage the agroecosystem, obtained from Alcon et al. (2017) and Lehtonen et al. (2020).

Table 3. About here.

In the experimental design, the attribute levels were combined by applying an S-efficiency design, using the Ngene 1.0.2 software package (Rose et al., 2010). The S-efficiency design was chosen for this study to minimise the sample size requirements (Rose and Bliemer, 2013) because of the small target population: the agroecosystem stakeholders in the Region of Murcia. The final design comprised 18 choice sets grouped into three blocks, which were randomly assigned to the stakeholders. Hence, each stakeholder was presented with six choice sets consisting of three alternatives each, which represented the different agroecosystems included in the case study: one alternative was the rainfed agroecosystem, used as the SQ alternative, and the other alternatives represented the irrigated agroecosystems. An example of a choice set is provided in Appendix A (Figure A.1).

3.2.2. Sampling and data collection: Stakeholder assessment

The AES and AEDS significant for agroecosystem valuation were assessed through face-to-face interviews with agroecosystem stakeholders of the Region of Murcia region (the target population). Agroecosystem stakeholders included farmers, agricultural technicians, irrigation community managers, agricultural R&D managers in private companies, members of scientific bodies such as universities and research institutes, public administrators, and local communities involved in agriculture (Alcon et al., 2014). Therefore, the stakeholders comprised any group or individual affecting or affected by the AES and AEDS (Hein et al., 2006). In accordance with this definition, relevant institutions and individuals involved in agricultural decision-making were identified and asked to participate. Thus, an initial selection of 10 stakeholders was identified and contacted for interviewing. Once the interviews began, a snowball sampling method was followed to select other relevant stakeholders (Biernacki and Waldorf, 1981; Reed et al., 2009). In total, 44 agroecosystem stakeholders[2] were successfully interviewed and classified into four key groups:

- Users (11): This group included farmers and technicians who worked directly in the agroecosystems.
- Researchers (10): This group comprised agronomic engineers, scientists, and economists who conducted research in the case study agroecosystems.
- Public managers (13): This group included managers from regional and national organisations responsible for water use and agricultural land management.
- Civil society (10): This group comprised NGOs, labour unions, political parties, and other associations.

The stakeholder interviews were conducted face-to-face, between July and September 2018, based on a two-part questionnaire. The first part concerned stakeholder perceptions and attitudes about the AES and AEDS provided by agroecosystems in the Region of Murcia, and the second part comprised the choice experiment. The stakeholders were asked to choose the agricultural system they would like to implement in the Region of Murcia.

Despite the extensive use of choice experiments in environmental economics, some limitations continue to arise from the employment of this method, mainly related to its hypothetical nature (Alemu and Olsen, 2018). The issue is whether the respondents' hypothetical choices would correspond to their actual behaviour if they faced similar choice situations in real life (Carlsson, 2010). Furthermore, the application of such a stated preference method, including environmental goods and services that are complex and unfamiliar to respondents, has been criticised on the basis that respondents cannot give accurate responses as their preferences are not fully discovered (Braga and Starmer, 2005). To mitigate these possible limitations, certain factors were taken into consideration in relation to sampling and data collection. The group of agroecosystem stakeholders interviewed comprised experts in their respective fields of agricultural work; therefore, it helped to ensure they were familiar with the choice situations they faced. In addition, two ex-ante strategies were applied to mitigate hypothetical bias (Loomis, 2014). First, prior to participating in the choice experiment, the respondents were thoroughly informed about the AES and AEDS used, the attributes and levels included, and the purpose of the study, using cheap talk

[2] The recommended number of experts interviewed for stakeholder assessment is 17 to 50 (Adler and Ziglio, 1996), in line with other studies performed in the case study area (Alcon et al., 2014) as well as other ecosystem services and disservices assessments (Wells et al., 2018; Jones et al., 2019). This number guarantees the minimum sample size requirement for the discrete choice experiment (De Bekker-Grobb et al., 2015).

script (Champ et al., 2009). Second, they were advised that the survey results would be employed to inform agricultural policy makers and, therefore, they would have an influence on future agricultural policies in the Region of Murcia.

3.2.3. Econometric framework

According to the random utility theory (McFadden, 1974), the utility U_{ij} for an individual i provided by an agroecosystem alternative j can be decomposed into a deterministic (V_{ij}) and a stochastic part (ε_{ij}), considered additively:

$$U_{ij} = V_{ij} + \varepsilon_{ij} = \sum_{k=1}^{K} \beta_k X_{ikj} + \varepsilon_{ij} \qquad k = 1, \dots, K \qquad (1)$$

where V_{ij} represents the observed elements of the utility determined by the k attribute levels (X_{ikj}), and ε_{ij} is a random error with an independent and identically distributed extreme-value distribution (Train, 2009). Assuming a linear relationship among the attribute levels, β_k is the individual marginal utility obtained from each k attribute, reflecting how the utility level changes if the provision of AES and AEDS increases.

The agroecosystem alternatives chosen by the respondents allow us to explore the probability of choosing an alternative j and to estimate the marginal utilities, β_{ik}, which maximise it. The conditional logit (CL) model (Train, 2009) is widely used to estimate the probabilities of such choices. Nevertheless, the CL model implies some restrictive assumptions (no random taste variation, restrictive substitution patterns, and no correlation of unobserved factors), the most relevant being the independence of irrelevant alternatives (IIA), which assumes that the probability of choosing an alternative is not influenced by the existence of any other alternatives. The IIA principle can be contrasted by the Hausman test (Hausman and McFadden, 1984). If the null hypothesis of the Hausman test is not rejected, the CL model is a suitable to estimate the stakeholders' utility function. However, if it is rejected, another specification model, such as the mixed logit model, should be employed instead.

A linear specification was employed to estimate the utility function. All attributes were assumed to be continuous variables, except *CHERIT*, *RECRE*, *LAND*, and RESL, which were assumed to be categorical. Preference heterogeneity was examined using the interactions between some attributes and the stakeholders' type. A positive sign for coefficients related to AES and a negative sign for those referring to AEDS were expected, but it was rather difficult to hypothesise which AES and AEDS would have a significant role in the explanation of the stakeholders' choices.

The results from the CL model were also used to calculate the relative importance or weight of each attribute. Adapting the Danner et al. (2017) procedure for continuous attributes, the relative importance of attribute k (RI_k) was calculated as follows:

$$RI_k = \frac{|\beta_k \bar{X}_k|}{\sum_{k=1}^{K} |\beta_k \bar{X}_k|} \quad (2)$$

where $\bar{X}_k$ represents the average of the attribute k, and RI_k represents, therefore, the relative contribution of the attribute k to the total utility, evaluated for the average value of each attribute.

4. RESULTS

The stakeholders' preferences were analysed using two CL models (Table 4). The CL model specification was appropriate since the Hausman test results (HT) validated the existence of IIA (HT = 10.03; $\chi^2_{0.05;11}$ = 19.675). Both Model 1 and Model 2 were based on the main-effects CL model, and Model 2 included stakeholder-group interactions. Significant differences between Model 1 and Model 2 were found with the log-likelihood ratio (LR) test (LR test = 31.234; $\chi^2_{0.05;3}$ = 7.815). Moreover, the accuracy of the choice models, which refers to the ability of both models to explain stakeholders' preferences in a precise manner, was evaluated through the pseudo-R^2 and the percent correctly predicted (PCC). Again, Model 2 performed better than Model 1 in terms of the pseudo-R^2, PCC, AIC, and BIC criteria; thus, it was used as the basis for further discussion of the results.

The Model 2 results showed a significant negative coefficient for the rainfed agroecosystem (SQ) alternative ($p < 0.01$), reflecting the disutility provided by this agroecosystem in terms of the AES and AEDS provided. The interaction terms between the SQ alternative and the stakeholder groups were significant, showing the heterogeneity of preferences among the stakeholder groups regarding the rainfed agroecosystem: the farmers perceived the highest disutility from the rainfed agroecosystem, followed by the researchers, public managers, and civil society.

Table 4. About here.

Analysis of the significance of the Model 2 coefficients to determine the AES and AEDS, which really explain the stakeholders' utility function, showed that the valuation of 6 out of 12 AES and AEDS was relevant. Of the provisioning services, the yield from agricultural activities (FOOD) ($p < 0.05$) and water supply for irrigation (WATER) ($p < 0.1$) explained the stakeholders' choices in terms of AES and AEDS, respectively. The positive sign of the FOOD coefficient indicated that higher farm yield levels were preferred by the stakeholders. The negative sign of the WATER coefficient confirmed the disutility of this attribute, indicating its relevance among the AEDS.

Regarding the regulation of AES and AEDS, significant coefficients were found for the attributes: temperature regulation (TEMP) and groundwater pollution (POLL) ($p < 0.01$) as well as for the agroecosystem contribution to biodiversity maintenance (BIOD) ($p < 0.05$). Therefore, local climate regulation is seen as an AES that can mitigate high temperatures in semi-arid areas. The negative sign of the POLL coefficient reflected the stakeholders' concerns about the environmental impact of agriculture in terms of pollution externalities, confirming the consideration of POLL as one of the AEDS. Bird richness is assumed to be a good indicator of biodiversity and should therefore be relevant among the AES provided by agroecosystems. The positive BIOD coefficient reflected the utility perceived by stakeholders for the enhancement of biodiversity within agricultural landscapes. The non-significant coefficients obtained for erosion (ERO) and carbon balance (CARBON) indicated their irrelevance to the stakeholders.

Despite the fact that in the literature there are many references to the impacts of cultural AES on human well-being, in agroecosystems, only recreation and leisure (RECREO) showed a significant effect ($p < 0.05$) on the stakeholders' utility function. Although the agricultural contribution to direct employment was expected to be significant due to the socioeconomic idiosyncrasy of the case study agroecosystems, the EMPGE attribute coefficient was not significant.

Therefore, according to the stakeholder preferences, two provisioning, three regulating, and one cultural AES and AEDS were identified as worthy of valuation, due to their notable impact on human well-being. Moreover, the coefficient sign reflected the positive or negative contribution to social welfare and verified our previous consideration of the attributes as either AES or AEDS. The coefficient signs for WATER and POLL were negative, corroborating their definition as AEDS, thus reflecting the disutility associated with higher attribute levels. The remaining significant agroecosystem services (FOOD, TEMPE, RECRE, and BIOD) had positive coefficient signs, showing that they were considered as AES by the stakeholders.

The results also enabled calculation of the relative importance of each of the significant AES and AEDS in the agroecosystem valuation (Figure 4). The stakeholders' choices revealed biodiversity (38%) as the most important of the AES to be valued, followed by recreation (20%), temperature regulation (7%), and food provision (5%). Among the AEDS, water supply for irrigation and groundwater pollution were considered of equal weight (at 15% each).

Figure 4. About here.

5. DISCUSSION

The analysis of stakeholders' preferences for AES and AEDS has been used to validate a comprehensive approach for the valuation of the AES and AEDS provided by semi-arid western Mediterranean agroecosystems. This approach is based on the framework for anthropised ecosystems developed by Barot et al. (2017), and it adapted the main accepted ecosystem services paradigms: MEA (2005), TEEB (2010), and CICES (Haines-Young and Potschin, 2018) to the particular case of agroecosystems. The stakeholder assessment enabled us to determine which AES and AEDS should be relevant for an agroecosystem valuation. Using choice experiments in the context of stakeholder assessment and AES and AEDS valuation, we considered the perceived trade-offs between AES and AEDS in an integrated way. The approach included at least one of the AES or AEDS from every category (provisioning, regulating, and cultural), in line with the multifunctional character of agricultural activity (Huang et al., 2015).

The approach presented here integrated AES and AEDS into a common valuation framework. The results from the stakeholder assessment revealed that the valuation of agroecosystems needs to deal with both positive and negative outcomes. Hence, negative contributions to human well-being should be included when the aim is to value the overall impact of agriculture on well-being. Indeed, Figure 4 shows that the relative importance that stakeholders attached to AEDS is 30% of the total. These results reinforce the claims of Schaubroeck (2017) and Blanco et al. (2019), who suggested an equal consideration of services and disservices, not only in economic valuation but also in research and policy agendas. Ignoring the values of AEDS when assessing agroecosystem contributions to human well-being could lead to overestimation of the benefits provided and thus to incorrect policy decisions, due to the undervaluation of costs. The holistic valuation of AES and AEDS could enable more efficient allocation of economic resources because it could be more cost-effective to mitigate disservices than to increase services (Shackleton et al., 2016). Consequently, these results could be used as a guide to improve our knowledge about the relative values that societies place on AES and AEDS.

The proposed approach also endorses the integration of provisioning and non-provisioning services, which traditionally have been considered separately in economic valuation (distinguished as marketed and non-marketed services). The economic valuation of agroecosystems could be developed either according to their capacity to provide services and disservices (supply-side valuation), or considering the social demand for the services and disservices provided by the agroecosystems (demand-side valuation). Supply-side valuation involves cost-based and production-based methods, which usually integrate all the types of services and disservices provided (Martín-López et al., 2014), whereas demand-side valuation involves preference-based approaches and, consequently, focuses on non-marketed services and disservices (Niedermayr et al., 2018). Thus, our results revealed that, although non-provisioning services were dominant (Figure 4), agroecosystem valuation needs to consider both services and disservices, consistent with the ongoing discussion in the literature (Bernués et al., 2019).

Considering all the AES and AEDS, it is not surprising that both provisioning services and disservices have been shown to be valuation relevant. Agroecosystems are ecosystems created by humans to provide food, therefore, the significance of provisioning services must be valued. However, in the present study, the relative importance of provisioning services in relation to the overall AES and AEDS to be valued was not as high as expected. Provisioning services represented approximately 20% of the total importance (Figure 4), in line with the findings of Bernués et al. (2019) for the Mediterranean region. This evidence indicates that the value of an agroecosystem goes beyond the direct use that the socioeconomic system obtains from it.

Regulating AES and AEDS are essential for agroecosystem assessment due to the relevance of their contribution to well-being, as they generate environmental benefits and costs, respectively. The findings of this study indicated that the relevance of both regulating AES and AEDS was broadly recognised by the stakeholders who stated that the indirect use value of regulating AES and AEDS is key to human well-being and valuated their relative importance in the case study agroecosystems at approximately 60% (Figure 4). These results are consistent with Bernués et al. (2019), who found that the indirect use value in a Mediterranean agroecosystem contributed 53.2% of the total value estimated. Of the regulating AES, climate regulation and maintenance of lifecycles and genetic diversity were relevant to the valuation. Temperature regulation, an indicator of local climate regulation, was rated as important by stakeholders in our study as it has a great influence on well-being; however, no significant effect was found for the indicator of global climate regulation. These findings may be related to the warm weather in the study area which is more easily perceived by stakeholders than climate change effects. This explanation is supported by Olander et al. (2017), who stated that people tend to value benefits that provide more direct and closer effects. Biodiversity was by far the most important of the regulating AES valued (Figure 4) in our study. The value of biodiversity comes from a great variety of sources (Paul et al., 2020), beyond its indirect use or option values. In addition, benefits can be obtained from biodiversity due to the positive effects it may have on human health (Sandifer et al., 2015), mainly through the emotional and psychological aspects of human well-being (Fuller et al., 2007; Dallimer et al., 2012). Regarding soil erosion, even though this regulating factor is important in certain agroecosystems, such as rainfed Mediterranean (Almagro et al., 2016) or diversified (Alcon et al., 2020b) agroecosystems, it was not considered relevant by the stakeholders who participated in the present study. Many of the consulted stakeholders, particularly in the *Users* and *Civil society* groups, did not consider soil erosion a major concern in the case study agroecosystems. This finding is supported by Cerdá et al. (2018), who determined that a number of citrus farmers did not consider soil erosion a problem in southeast Spain. However, the perceived lack of importance of soil erosion may be related to a lack of environmental education and awareness regarding soil erosion and conservation issues (Oñate and Peco, 2005; Sastre et al., 2017). A similar statement could be made about resilience. Despite its noticeable importance in guaranteeing agricultural sustainability under natural hazards and climate change (Peterson et al., 2018), stakeholder awareness of the negative impacts of climate change appears to be lacking (Esteve et al., 2018).

The cultural services provided by agroecosystems have social benefits generally associated with the use and enjoyment of these environments. Our results showed that, among the cultural AES valuated, leisure and recreation were perceived to have significant influences on well-being greater than those of the landscape, cultural heritage, and cognitive development. In fact, leisure and recreation is considered the broadest service and can partially encompass other cultural AES (García-Llorente et al., 2012). In this case study, to a certain extent, attributes such as the landscape and cultural heritage linked to the agroecosystems and their relative importance approached 20%, contrasting with Bernués et al. (2019) who found that cultural services represented 8% of the overall demand for AES. However, Martínez-Paz et al. (2019) determined that cultural services accounted for 42% of the relative importance of the AES provided by the Huerta of the Region of Murcia, a specific agroecosystem located within the traditionally irrigated agroecosystem in the case study area. These differences in relative importance of cultural services again show the importance of contextual background for understanding the results obtained from the valuation of AES and AEDS.

Water management is crucial for semi-arid Mediterranean farming. The Mediterranean area in general, and the case study area in particular, are characterised by a semi-arid climate, which makes dealing with water scarcity one of the main challenges in these agroecosystems. This fact was reflected in the stakeholder utility function as the only two significant AEDS in the explanation of the stakeholder choices were related to water management. Supplying water for irrigation is perceived to cause a reduction in available water resources, which are indeed limited. This could imply, in turn, an opportunity cost, because alternative uses of water show higher water-productivity values. The rivalry associated with competing uses of water resources and the social dilemma of supplying reclaimed water to competing ecosystems, is highlighted by Zabala et al. (2019) in their Region of Murcia case study. Moreover, these concerns refer not only to water employed as an input to agroecosystems, but also to water flows supplied by agroecosystems. Either frequent or excessive nitrogen fertilisation could have negative consequences for the agroecosystem and surrounding ecosystems. Aquifers are particularly affected by agroecosystem nitrate leaching and runoff. Therefore, the recognition by stakeholders that agroecosystems contribute negatively to water purification and waste treatment evidences the negative externality supplied by agricultural activity, which would be mitigated only if wastewater coming from agricultural systems could be properly treated (Sepehri and Sarrafzadeh, 2018; Sepehri et al., 2020). This implies not only evident environmental costs, but also economic and social costs, especially when nitrate runoff reaches high-value ecosystems, as occurs in the case study area where the Mar Menor coastal lagoon is impacted (Velasco et al., 2018). Hence, the joint consideration of AES and AEDS for water management seems to be a key element in semi-arid Mediterranean agroecosystem valuation.

The implications of the findings of this case study could be applied to improve agricultural policy design. Policy makers need to boost the provision of the most relevant AES, while mitigating AEDS, in accordance with case-specific agroecosystems and their surrounding areas. Increasing human well-being in semi-arid western Mediterranean agroecosystems implies the enhancement of food provision, local climate regulation, biodiversity, and recreational activities within the agroecosystems. In addition, this should be supported with measures or strategies focused on reducing the water supply for irrigation, such as regulated deficit irrigation, and mitigation of diffuse pollution from agricultural systems (Alcon et al., 2020a). We note that the findings of the present study could not be used as a tool to publicly support the transition from other land uses to agroecosystems (e.g. to support forest conversion) because land use changes, which may imply the transition from or to other ecosystem types, were not considered in our agroecosystem assessment approach. The integration of land use changes and ecosystem services and disservices, where agroecosystems might play a key role, should be considered in future research.

6. CONCLUSIONS

Determination of the most relevant AES and AEDS for valuation was the main motivation of this study. To accomplish this, it was necessary to adapt the existing ecosystem services paradigms to the particular case of the agroecosystem. Therefore, a comprehensive approach for AES and AEDS was proposed and validated by stakeholder assessment. Determining the stakeholder preferences enabled us to establish the AES and AEDS that semi-arid western Mediterranean agroecosystem valuation should include: food provision and fresh water (as provisioning services), local climate regulation and wastewater treatment (as regulating services), the contribution to recreation and tourism (as cultural services), and biodiversity.

Regarding management implications, the results indicated that an increase in human well-being comes from the following: promotion of agricultural and natural resources, policies that maximise the agricultural contribution to food provision, reduction of the water supply for irrigation, lowering of the local temperature, minimising groundwater pollution, creation of an environment that supports recreational and leisure activities, and encouraging biodiversity conservation. Therefore, this comprehensive approach serves to raise awareness of the need to consider AES and AEDS holistically in agri-environmental policy design. This approach will be a key tool for forthcoming agroecosystem economic valuations, which will translate the social demand for AES and AEDS into monetary terms, and will ensure efficiency in the design of socially acceptable agri-environmental schemes.

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TABLES

Table 1. Main ecosystem service classifications and proposal for agroecosystems

	MEA (2005)	TEEB (2010)	CICES (2018) (Division | Group)	Agroecosystem proposal (AES/AEDS)
Provisioning services	Food	Food	Biomass | Cultivated terrestrial plants for nutrition, materials or energy production	Food (AES)
	Fibre	Raw materials, ornamental resources		
	Biochemicals	Medicinal resources		
	Genetic resources	Genetic resources	Genetic material from all biota (including seed, spore or gamete production) | Genetic material from plants, algae or fungi	
	Fresh water	Water	Water | Surface/Groundwater used for nutrition, materials or energy production	Water (AEDS)
Regulating services	Air quality regulation	Air quality regulation	Transformation of biochemical or physical inputs to ecosystems | Mediation of nuisances of anthropogenic origin	Emissions of contaminants to the atmosphere (AEDS)
	Global climate regulation	Climate regulation	Regulation of physical, chemical and biological conditions | Atmospheric composition and conditions	Global climate regulation (AES)
	Local climate regulation	Climate regulation	Regulation of physical, chemical and biological conditions | Atmospheric composition and conditions	Local climate regulation (AES)
	Water regulation	Regulation of water flows	Regulation of physical, chemical and biological conditions | Water conditions	(Not included – *service overlapping*)
	Water purification and waste treatment	Waste treatment	Transformation of biochemical or physical inputs to ecosystems | Mediation of wastes or toxic substances of anthropogenic origin by living processes	Water purification and waste treatment (AES/AEDS)
	Erosion regulation	Erosion prevention	Regulation of physical, chemical and biological conditions | Regulation of baseline flows and extreme events	Soil maintenance (AES/AEDS)
	Soil formation (supporting)	Maintenance of soil fertility	Regulation of physical, chemical and biological conditions | Regulation of soil quality	
	Disease regulation	Biological control	Regulation of physical, chemical, biological conditions | Pest and disease control	Biodiversity (AES/AEDS)
	Pest regulation			
	Pollination	Pollination	Regulation of physical, chemical and biological conditions | Lifecycle maintenance, habitat and gene pool protection	
	-	Maintenance of lifecycles of migratory species, maintenance of genetic diversity	Regulation of physical, chemical and biological conditions | Lifecycle maintenance, habitat and gene pool protection	
	Natural hazard regulation	Moderation of extreme events	Regulation of physical, chemical and biological conditions | Regulation of baseline flows and extreme events	Resilience (AES)
Cultural services	Spiritual and religious values	Inspiration for culture, art and design, spiritual experience	Indirect, remote, often-indoor interactions with living systems that do not require a presence in the environmental setting | Spiritual, symbolic and other interactions with the natural environment	Culture, art and design (AES)
	Aesthetic values	Aesthetic information	Direct, *in-situ* and outdoor interactions with living systems that depend on a presence in the environmental setting | Intellectual and representative interactions with the natural environment	Aesthetic values (AES)
	Recreation and ecotourism	Opportunities for recreation and tourism	Direct, *in-situ* and outdoor interactions with living systems that depend on a presence in the environmental setting | Physical and experiential interactions with the natural environment	Opportunities for recreation and tourism (AES)
		Information for cognitive development	Direct, *in-situ* and outdoor interactions with living systems that depend on a presence in the environmental setting | Intellectual and representative interactions with the natural environment	Cognitive development and good living (AES)

Table 2. AES and AEDS, typology of benefits/costs and values

				Type of benefit/cost			Type of value			
	Agroecosystem (AES/AEDS)	**Benefit**	**Cost**	**Economic**	**Environmental**	**Social**	**Direct use**	**Indirect use**	**Option**	**Non-use**
Provisioning services	Food (AES)	*x*		*x*		*x*	*x*		*x*	
	Irrigation water (AEDS)		*x*	*x*	*x*		*x*		*x*	
Regulating services	Emissions of contaminants to the atmosphere (AEDS)		*x*		*x*			*x*	*x*	
	Global climate regulation (AES)	*x*			*x*			*x*	*x*	
	Local climate regulation (AES)	*x*			*x*			*x*	*x*	
	Water purification and waste treatment (AES/AEDS)		*x*	*x*	*x*	*x*		*x*	*x*	*x*
	Soil maintenance (AES/AEDS)	*x*	*x*	*x*	*x*			*x*	*x*	
	Biodiversity (AES/AEDS)	*x*	*x*		*x*	*x*	*x*	*x*	*x*	*x*
	Resilience (AES)	*x*			*x*			*x*	*x*	
Cultural services	Culture, art and design (AES)	*x*				*x*		*x*	*x*	*x*
	Aesthetic values (AES)	*x*				*x*	*x*		*x*	*x*
	Opportunities for recreation and tourism (AES)	*x*		*x*		*x*	*x*		*x*	
	Cognitive development and good living (AES)	*x*		*x*		*x*	*x*		*x*	

Table 3. Attributes and levels in the choice experiment

	Agroecosystem (AES/AEDS)	Attribute (CODE)	Definition (Indicator)	Units	Levels
Provisioning services	Food (AES)	Yield (FOOD)	Annual incomes received by farmers	€/ha/year	< 5,000* 5,000 - 15,000 > 15,000
	Irrigation water (AEDS)	Water supply for irrigation (WATER)	Irrigation water supplied to crop system	m^3/ha/year	< 3,000* 3,000-5,000 > 5,000
Regulating services	Emissions of contaminants to the atmosphere (AEDS) Global climate regulation (AES)	Carbon balance (CARBON)	Net balance between CO_{2eq} sequestration and emission	tonnes CO_{2eq}/ha/year	< 15* 15-30 > 30
	Local climate regulation (AES)	Temperature regulation (TEMPE)	Temperature changes on the land surface	ºC	0* -1 ºC -2 ºC
	Water purification and waste treatment (AEDS)	Groundwater pollution (POLL)	Nitrate concentration in aquifers	mg NO_3^-/L	< 50* 50-200 > 200
	Soil maintenance (AES/AEDS)	Erosion (EROS)	Loss of soil due to wind or precipitation	-	High* Low
	Biodiversity (AES/AEDS)	Bird species richness (BIOD)	Bird species richness with respect to potential	%	100 % 80 %* 60 %
	Resilience (AES)	Resilience (RESL)	Agroecosystem's climate change adaptation	-	High* Low
Cultural services	Culture, art and design (AES)	Cultural heritage (CHERIT)	Presence of cultural elements linked to agriculture	-	No* Yes
	Aesthetic values (AES)	Landscape (LAND)	Scenic landscape beauty	-	Rainfed agroecosystem* Traditional irrigated agroecosystem Highly-intensive irrigated agroecosystem
	Opportunities for recreation and tourism (AES)	Recreation and tourism (RECRE)	Chance of enjoying activities in agroecosystems	-	No* Yes
	Cognitive development and good living (AES)	Employment generation (EMPGE)	Labour related to agroecosystems management	hours/ha/year	< 100* 100-500 > 500

*Attribute levels which comprise the SQ alternative (rainfed agroecosystem)

Table 4. Stakeholders' utility function. Estimated CL models.

	Model 1			Model 2		
	CL model			CL model and stakeholder heterogeneity		
	Coef.		Std. Err.	Coef.		Std. Err.
SQ	-0.874		0.812	-2.889	***	0.987
FOOD	$3.32 \cdot 10^{-5}$	**	$1.58 \cdot 10^{-5}$	$3.21 \cdot 10^{-5}$	**	$1.61 \cdot 10^{-5}$
WATER	$-2.23 \cdot 10^{-4}$	*	$1.28 \cdot 10^{-5}$	$-2.33 \cdot 10^{-4}$	*	$1.32 \cdot 10^{-4}$
CARBON	0.017		0.011	0.016		0.011
TEMPE	0.406	***	0.150	0.423	***	0.155
POLL	-0.009	***	0.001	-0.009	***	0.002
EROS	-0.250		0.260	-0.182		0.267
BIOD	0.018	**	0.009	0.018	**	0.009
RESIL	0.120		0.285	0.04		0.290
CHERIT	-0.083		0.254	-0.101		0.263
LAND	0.349		0.257	0.349		0.264
RECRE	0.835	***	0.254	0.763	***	0.260
EMPGE	$2.46 \cdot 10^{-5}$		0.001	$-1.20 \cdot 10^{-4}$		0.001
RESEARCHER*SQ				1.721	***	0.617
PUBLIC MANAGER*SQ				2.161	***	0.577
SOCIETY*SQ				2.696	***	0.597
Number of observations	792			792		
Log likelihood	-243.456			-227.839		
Pseudo R^2	0.161			0.214		
PCC (%)	70.960			74.490		
AIC	512.911			487.677		
BIC	573.681			562.470		

Statistically significant at a level of *0.1, **0.05 and ***0.01.

FIGURES

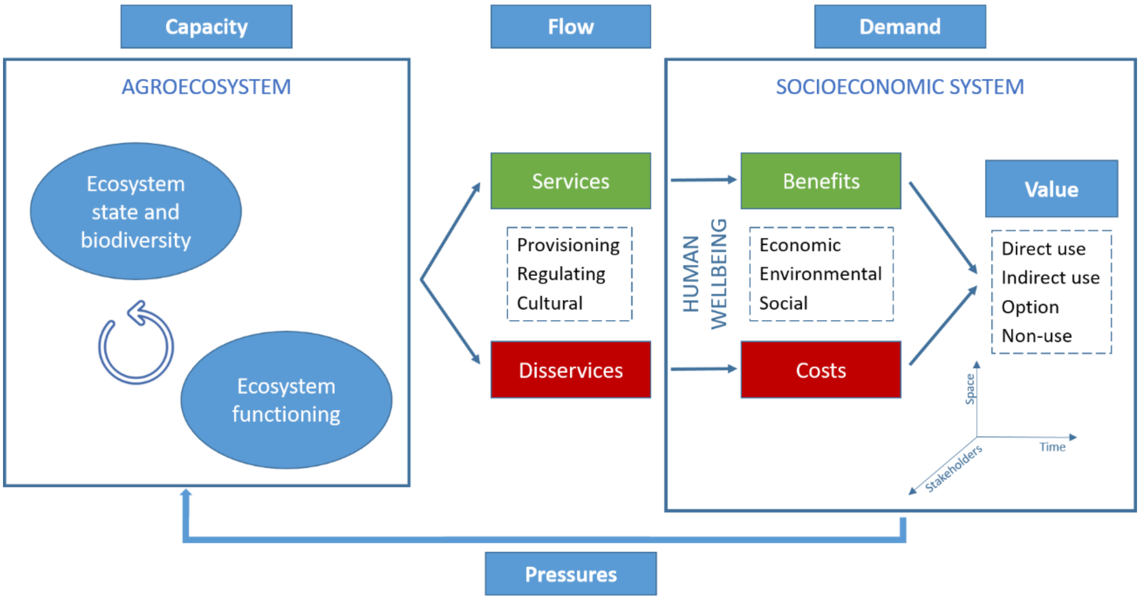

Figure 1. Conceptual approach linking agroecosystem functioning, services and disservices, value and agricultural practices. It is based on the "Capacity, Flow, Demand and Pressure" framework (Villamagma et al., 2013) and the TEEB valuation framework.

Source: Own elaboration, adapted from Barot et al. (2017) and TEEB (2010).

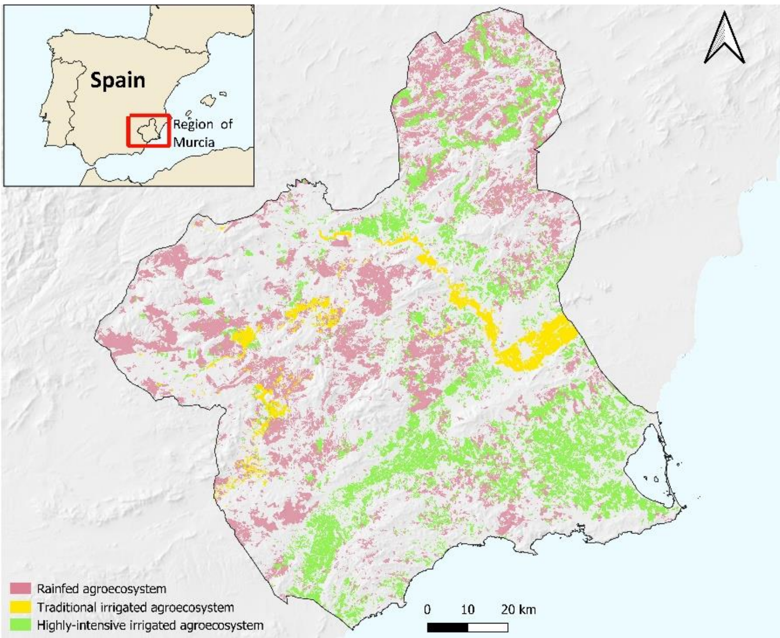

Figure 2. Case study. Region of Murcia (south-eastern Spain)

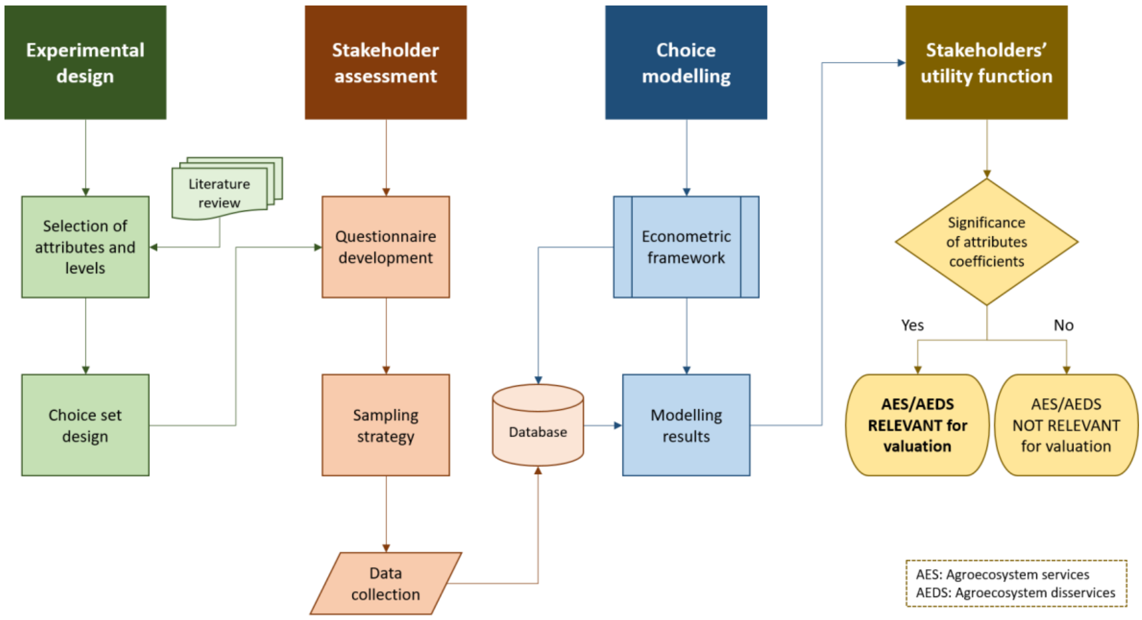

Figure 3. Process followed to implement the choice experiment method.

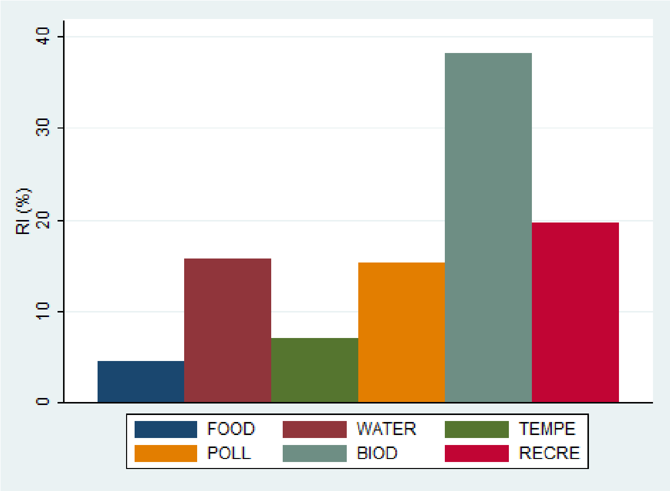

Figure 4. Relative importance (RI) of the AES/AEDS for valuation.