Spatial heterogeneity of WTP values for sparsely-located ecosystem services: alternative index approaches applied to agricultural systems

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ABSTRACT

Previous studies demonstrate the existence of spatial heterogeneity in the demand for ecosystem services (ES), especially by showing spatial discounting (namely, distance decay) and the effect of substitute sites. Our study adds to this literature by analyzing diverse ways of modeling these two effects and applying them to a scattered ecosystem which provides various ES. For this purpose, novel spatial approaches using different discounting factors and incorporating the presence of substitutes (density-based vs. area-based indexes) have been tested. The analysis is based on a discrete choice experiment (DCE) focusing on the estimation of willingness to pay (WTP) for the ES provided by olive groves in Andalusia (southern Spain). For the econometric specification, we use random parameter logit models in preference space to assess the performance of the proposed spatial indexes. The results show that the introduction of these spatial indexes significantly improves the fit of the models, with the best outcome found for the area-based index combined with the inverse of the distance. In addition, differences are found depending on the ES. For biodiversity and soil conservation (i.e., predominantly use values), a positive relationship between WTP and the spatial index is found, implying that the larger the nearby olive grove area, the larger individuals' WTP, while the opposite is found for carbon sequestration (i.e., predominantly non-use value). These results have important implications for the design of public policies aimed at improving the agricultural provision of ES.

Keywords: Spatial Analysis, Willingness to pay, Choice Experiments, Ecosystem Services, Olive Growing.

1. Introduction

Agricultural systems provide a wide range of ecosystem services (ES) (Swinton et al., 2007), most of them demanded by society. As they lack markets to adequately incentivize their provision, governments usually play a significant role in promoting their provision at the socially-desired levels (Pannell, 2008). However, these levels are often unknown given the lack of information about the value attached to the ES. Therefore, the economic valuation of these non-market services is utterly essential to support policy decision-making aimed at promoting a smart provision of ES by agricultural systems (Rogers et al., 2015).

The economic valuation of ES has been the subject of much research, with special emphasis on natural sites (see Ferraro et al., 2012 for an extensive review) and, to a lesser extent, agro-ecosystems (Madureira et al., 2013). Within the specialized literature, the need to incorporate the spatial dimension has long been evidenced (e.g., Loomis, 2000, Schaafsma, 2015). Spatially-explicit information on values derived from ES is important for two main reasons: the determination of economic jurisdiction and usefulness for benefit-transfer. With regard to the former, it is key to determine the size of the economic jurisdiction for each case, in order to reflect the geographical area where the population with significant willingness to pay (WTP) (beneficiaries) for environmental improvements lives. Thus, total welfare changes are estimated as the aggregate WTP of individuals living in that jurisdiction (Bateman et al., 2006). Moreover, information on the economic jurisdiction is useful to determine the most suitable political jurisdiction to manage the design, implementation, and financing of environmental policy instruments (Loomis, 2000). With regard to the latter, by using information on the spatial heterogeneity of WTP for environmental services, benefit-transfer applications can be more accurate, thus leading to lower transfer errors (Johnston et al., 2018).

Studies focusing on spatial analysis of individuals' preferences towards ES have shown that a variety of effects relates to spatial factors. Among these, distance-decay (i.e., the negative relationship between values and the distance between the site of supply and the individual's residence) probably stands out as the most widely known (Hanley et al., 2003, Bateman et al., 2006). However, there are other spatial factors that influence the values attached to ES, which revolve around the type of value (use and non-use) attached to the service (Hanley et al., 2003), the presence of substitutes in the nearby areas (Jørgensen et al., 2013), and directional aspects (Agee y Crocker, 2010, Schaafsma et al., 2012).

Additionally, spatial assessments of WTP for ES have regularly focused on the analysis of single concentrated sites (e.g., a natural park), while more complex locations, such as sparsely located sites, have received much less attention. A few applications focus on sites of the latter type, including forest areas (Czajkowski et al., 2017) and riparian zones (Holland y Johnston, 2017), whereas to the authors' knowledge there is no study focusing on agricultural systems. If we consider substitutability and directional issues, it is easy to observe that distance-decay models can perform poorly compared to area- and density-based models when applied to these sparsely-located ecosystems (Lizin et al., 2016, Budziński et al., 2017).

Therefore, this paper aims to contribute to the existing literature in two ways: first, by providing empirical evidence on the spatial heterogeneity of values derived from the ES provided by sparsely-located agricultural systems; and second, by delivering methodological insights into the use of different area- and density-based approaches to analyze such heterogeneity. To achieve both objectives, we use data from a discrete choice experiment carried out to valuate individuals' WTP for ES for the case study of the olive groves agricultural system located in Andalusia (southern Spain). We use a random parameter logit approach to explore heterogeneity with different area and density indexes, which, to our knowledge, are used here for the first time.

2. Materials and methods

2.1. Olive growing in Andalusia

Olive groves are the most representative agroecosystem of Andalusia. They occupy more than 1.5 million hectares (30% of the region's Utilized Agricultural Area), and are an important element in employment and income generation in the majority of Andalusian rural areas, often contributing to areas of high-environmental and landscape value (Villanueva et al., 2015). Olive groves are mainly located in central and north-eastern areas, although they can also be found scattered across the rest of the region.

In addition to their socio-economic importance, olives groves are also characterized by a remarkable provision of ES, mainly related to biodiversity, mitigation of climate change, and soil conservation. With regard to biodiversity, olive groves in Andalusia have traditionally been extensively managed, typically characterized as a low-input rain-fed agricultural system associated with high levels of fauna and flora. Indeed, species closely associated with the crop—mainly semi-natural vegetation, reptiles, and birds—are found extensively in traditional olive groves; as a result, this agricultural system is considered high nature value farmland (Paracchini et al., 2008). However, with the proliferation of new plantations, often highly-intensive monovarietal groves relying on irrigation, the monoculture of olive groves has sharply increased, resulting in growing pressures on the biodiversity associated with this agricultural system (Gómez-Limón et al., 2012).

When it comes to mitigating climate change, olive groves, just like any other permanent crop, can keep significant carbon stocks in their woody tissue. Additionally, they offer greater potential for carbon sequestration in soils; in particular, the use of soil-friendly management practices and organic fertilization is reported to result in remarkable improvements in carbon sequestration in olive groves (Aguilera et al., 2014).

Olive growing also plays a significant role with regard to the provision of ES related to soil conservation. Like biodiversity and mitigation of climate change, there is great potential for improvements in the provision of ES related to soil conservation, especially since most of the olive groves are located in areas with moderate to steep slopes, usually suffering from high soil erosion rates. In this regard, the spread of soil conservation techniques can significantly reduce the erosion risk, contributing to an improvement in soil fertility and an increase in organic matter (Gómez Calero et al., 2009).

The abovementioned ES (biodiversity, carbon sequestration and soil conservation) have different characteristics with regard to their value (use and non-use values) and scale (*global* services versus *local* services). In this sense, carbon sequestration can be considered mainly as a non-use, global service (people all over the world can benefit from the carbon sequestered by any agricultural system). Soil conservation is primarily viewed as a local service (the individuals that have the most to gain from reduced soil erosion are those who live nearby), so it can be argued that use values prevail over non-use values. With respect to biodiversity, the scope is more varied. Whereas it can be seen as a global service (i.e., people all over the world can benefit from an increase in biodiversity in any place), its links with other services such as landscape, also give it a significant local dimension. As a result, at local level, use values often prevail over non-use ones.

2.2. Methodological proposal for spatial analysis in sparsely-located systems

The distance to environmental sites may well be an inappropriate measure for explaining the heterogeneity in individuals' WTP for scattered ecosystems, like most agricultural systems. For this reason, we propose a set of spatial indexes suitable for both area- and density-based approaches allowing spatial discounting (De Valck et al., 2017).

To do so, it is necessary to know the location of every respondent's residence. Once the location of each respondent has been identified, the next step is to calculate the area of olive groves at different distances. To that end, a set of 10 km-wide annuli (or ring buffer zones) are created for every individual location using GIS techniques, until the whole Andalusian region is covered. These annuli are then intersected with the Andalusian olive grove cartography, thus yielding the area of olive groves included in every annulus.

Using this information, six indexes are calculated, with three being area-based and the other three being density-based; the two cases differ in the way the spatial discount effect is considered. They are calculated using the following expressions:

$$AREA\_INV = \frac{1}{10{,}000} \times \sum_{i=1}^{n} \frac{1}{d_i} \times Olive\_area_i \qquad (1)$$

$$AREA\_INV2 = \frac{1}{1{,}000} \times \sum_{i=1}^{n} \frac{1}{{d_i}^2} \times Olive\_area_i \qquad (2)$$

$$AREA\_INVLN = \frac{1}{100{,}000} \times \sum_{i=1}^{n} \frac{1}{\ln d_i} \times Olive\_area_i \quad (3)$$

$$DENS\_INV = 10 \times \sum_{i=1}^{n} \frac{1}{d_i} \times \frac{Olive\_area_i}{Total\_area_i} \quad (4)$$

$$DENS\_INV2 = 100 \times \sum_{i=1}^{n} \frac{1}{{d_i}^2} \times \frac{Olive\_area_i}{Total\_area_i} \quad (5)$$

$$DENS\_INVLN = \sum_{i=1}^{n} \frac{1}{\ln d_i} \times \frac{Olive\_area_i}{Total\_area_i} \quad (6)$$

2.3. Choice experiment approach: Attributes, levels and questionnaire design

Stated-preference approaches are the most suitable valuation methods to measure the well-being people obtain from the consumption of ES provided by agricultural systems, enabling estimates of the WTP including both use and non-use values. Since olives groves are indeed characterized by the joint provision of ES, we have considered Discrete Choice Experiments (DCE) the most suitable valuation approach. In order to implement this valuation method, we select four attributes, three non-monetary and one monetary (see Table 1). The first three relate to the main ES provided by Andalusian olive groves, namely carbon sequestration, soil conservation, and biodiversity. For these non-monetary attributes, moderate and significant improvements in their provision levels were defined. To facilitate the communication of these improvements to the respondents, proxy variables were defined for each attribute. The monetary attribute was defined as an annual increase in taxes during a 20-year period and levels were selected according to a pre-test survey consisting of a WTP open-ended question.

Table 1 Attributes, levels and proxy variables used in the choice set design.

Attribute	Technical variable	*Proxy* variable	Levels[a]
CO_2 sequestration	CO_2 sequestered annually in olive groves in Andalusia	Emission reduction equivalent to the emissions of a city of…	Status quo: 300,000 inhabitants Moderate improvement [CSEQ500]: 500,000 inhabitants Significant improvement [CSEQ700]: 700,000 inhabitants
Soil conservation	Annual reduction of soil erosion rates in olive groves in Andalusia	Soil erosion in olive grove area equivalent to…	Status quo: 30 Olympic stadiums Moderate improvement [SOIL16]: 16 Olympic stadiums Significant improvement [SOIL2]: 2 Olympic stadiums
Biodiversity	Increase in the number of bird species in olive groves in Andalusia	Average number of different bird species per hectare of…	Status quo: 10 bird species Moderate improvement [BIOD15]: 15 bird species Significant improvement [BIOD20]: 20 bird species
Payment	Annual willingness to pay for the next 20 years	Annual increase in taxes during the next 20 years of…	Status quo: 0 €/year Level 1: 15 €/year Level 2: 30 €/year Level 3: 45 €/year

Source: Rodríguez-Entrena et al. (2014).

Before being presented with the sequence of choice cards, the interviewees were informed of the current level of provisioning ES provided by olive groves in Andalusia and the potential improvement through changes in farm management. To avoid hypothetical bias, respondents were reminded of their budget constraints, and a "cheap talk" was also included in the interview.

Additionally, a follow-up question was designed to delve into the reasons for respondents' unwillingness to financially support the program, distinguishing protest responses from real zeros. The questionnaire ended with a set of questions related to the socio-economic characteristics of the respondents, as well as their attitudes toward the ES under analysis.

2.4. Econometric specification

To analyze the choices between alternative programs of ES provision, random parameter logit specifications with an error component were used (EC_RPL).

Three types of EC_RPL models were used in the analysis: one without considering any spatial index (Base Model), one interacting the spatial index considered in each model with the monetary attribute (Spatial Model 1), and one with all the attributes (Spatial Model 2). The last two models are used to show the improvements in model fit achieved by incorporating spatial heterogeneity, while the first one serves as a reference. For each of these two models, the different types of indexes (area- and density-based) described in Section 2.2 were used as sources of observed heterogeneity. To test for differences in goodness-of-fit of alternative models, the log-likelihood ratio test was used for nested specifications, and the Vuong test for non-nested specifications (Vuong, 1989)[1].

Models were estimated using 1000 Halton draws. All attributes were assumed to follow a normal distribution, except for the monetary attribute, which is assumed to follow a constrained triangular distribution.

2.5. Data gathering: experimental design and sample selection

Respondents were offered three options (alternatives) of ES outputs, one of which represents the *status quo* situation without additional payment. We estimated an optimal-in-difference fractional factorial design following the methodological proposal of Street y Burgess (2007), from which a total of 324 choice sets were obtained (the overall number of potential choice sets would be $(3^3 \text{ x } 4)^2$). These 324 choice sets were randomly assigned to 36 choice blocks with 9 choice sets each. During the pilot interviews, no saturation effect due to this number of choices was detected (Rodríguez-Entrena et al., 2014).

Regarding the study of spatial heterogeneity of values for sparsely-located ES, random sampling is unlikely to provide a geographically representative sample, for two reasons (Concu, 2007). Instead, for this investigation, where the target population analyzed to assess the proposed improvement in the provision of ES was the Andalusian population aged 18 or over (6.54 million inhabitants), sample selection was carried out following a multi-stage cluster approach. The primary sample units (municipalities) were selected following a random

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[1] The Vuong test is a likelihood-ratio-based test which tests the null hypothesis that the expected value of the difference vector of log-likelihood ratios for competing models equals zero, indicating that there is no evidence of superior fit among alternative specifications. As the statistic estimated with the Vuong test follows a standard normal distribution, the critical value of 1.96 corresponds to a 5% level of significance, which means that if the test exceeds that threshold in absolute values, there is evidence of the existence of a superior specification.

procedure, considering their size (rural, intermediate or urban), whereas the final sample units (individuals) were selected by random routes, imposing sex and age quotas. Moreover, in order to ensure that spatial heterogeneity could be estimated reliably, the sampling strategy implemented involved confirming that the sample drawn was also stratified according to the area and density indexes considered for the analysis (Schaafsma, 2015).

Fieldwork was carried out between February and April 2011 by a market research company. The research team trained and monitored the interviewers in the initial stage of the questionnaire implementation to ensure that it was correctly administered. The final sample consisted of 476 individuals.

3. Results and discussion

3.1. Alternative approaches for spatial analysis

Table 2 shows the main goodness-of-fit statistics (Pseudo-R^2 and AIC/N) for spatial models 1 and 2 and the six spatial indexes considered, as well as those for the Base Model. Table 3 shows the comparison in terms of goodness-of-fit between the Base Model and Spatial Model 1, and between Spatial Model 1 and Spatial Model 2, using the likelihood ratio (LR) statistic. While models show a high goodness-of-fit regardless of the specification (see Table 2), the results shown in Table 3 suggest that modeling can be significantly improved (at the 0.1% level) by incorporating spatial indexes as interaction terms, both with the monetary attribute alone and –even more so– with all the attributes for any of the spatial indexes proposed.

Table 2 Model fit statistics with the six spatial indexes.

	Spatial Model 1 (payment interaction)		Spatial Model 2 (payment and ES interactions)	
	Pseudo-R2	AIC/N	Pseudo-R2	AIC/N
AREA_INV	0.560	0.976	0.563	0.970
AREA_INV2	0.558	0.979	0.561	0.975
AREA_INVLN	0.561	0.973	0.563	0.971
DENS_INV	0.558	0.978	0.561	0.975
DENS_INV2	0.557	0.982	0.559	0.979
DENS_INVLN	0.560	0.976	0.561	0.975

Base Model (without any spatial index): Pseudo-R2: 0.554; AIC/N: 0.988.

Table 3 Results of the likelihood ratio test for nested models.

	Spatial Model 1 *vs* Base Model		Spatial Model 2 *vs* Spatial Model 1	
	LR statistic	Critical X^2 (DF)	LR statistic	Critical X^2 (DF)
AREA_INV	55.74***	5.99 (2)	36.34***	12.59 (6)
AREA_INV2	40.54***	5.99 (2)	28.96***	12.59 (6)
AREA_INVLN	65.96***	5.99 (2)	21.32***	12.59 (6)
DENS_INV	44.64***	5.99 (2)	26.20***	12.59 (6)
DENS_INV2	28.00***	5.99 (2)	26.38***	12.59 (6)
DENS_INVLN	55.86***	5.99 (2)	15.20***	12.59 (6)

*** denotes significance at 0.1% level.

As shown in Table 2, the models based on the different indexes have similar values in terms of goodness-of-fit statistics, and there are no notable differences that would allow conclusive results to be drawn from their comparison.

In order to test for significant differences in the goodness-of-fit statistics, we carried out the Vuong test for the Spatial Model 2 specification (see Table 4). As can be seen, the only model that shows significantly better performance when compared to the others is that based on the combination of the area and the inverse of the distance (i.e., the AREA_INV index). This result would be contrary to the initial hypothesis regarding the best approach for incorporating substitutes (i.e., the superiority of density- over area-based approaches). This counterintuitive result could, however, be explained by the implicit assumption that all the other land uses apart from olive growing (substitute sites) have equal levels of ES provision. Clearly, our results from comparing these two spatial approaches point to the need for further research focusing on the heterogeneity of ES provision of substitute sites, and the development of new density-based indexes able to take account of different substitute sites (i.e., land uses) with distinct levels of provision of ES.

Table 4 Results of the Vuong test for non-nested models (considering Spatial Model 2 specification only).

	AREA_INV	AREA_INV2	AREA_INVLN	DENS_INV	DENS_INV2	DENS_INVLN
AREA_INV	---					
AREA_INV2	-5.08***	---				
AREA_INVLN	-3.67***	0.91	---			
DENS_INV	-4.49***	-1.17	-1.67	---		
DENS_INV2	-4.45***	0.41	-0.79	1.35	---	
DENS_INVLN	-3.28***	1.00	0.01	1.76	1.00	---

*** denotes significance at 0.1% level. A negative (positive) sign means that the model in the column (row) outperforms the model in the row (column).

3.2. Demand for ES provided by olive farming

As has been pointed out in the previous section, the model based on the AREA_INV index has significantly better goodness-of-fit statistics than the equivalent models based on the other indexes. Therefore, we now present only the results regarding the demand for ES provided by olive farming yielded by the models based on AREA_INV.

Table 5 shows the results of the Base Model and the two spatial models (Spatial Model 1 and 2 using AREA_INV index). As can be seen, all the main effect parameters are significant and have the expected sign (i.e., positive for the ES parameters and negative for the payment parameter). With regard to the spatial heterogeneity, the interaction of the spatial index with the payment parameter is significant and positive in both spatial models. This indicates that the benefits stemming from the ES increase with increasing values of the AREA_INV index. Therefore, this means that *–ceteris paribus–* the larger the olive grove area nearby (i.e., higher AREA_INV index), the higher the WTP for the ES provided by this agricultural ecosystem. As a result, the spatial effect on the demand for ES provided by olive groves is found to be significant, which corroborates the initial hypothesis and is coherent with the results found in most of the previous studies (Schaafsma, 2015). Furthermore, when the spatial index is included, Spatial Model 2 shows three additional significant interaction parameters, namely those with CSEQ500, CSEQ700 and SOIL2, all of which are negative, implying an opposite effect to that explained above for the payment interaction. Indeed, these interactions indicate a lower intensity of preferences toward the provision of ES related to carbon sequestration and soil conservation when the nearby olive grove area is larger.

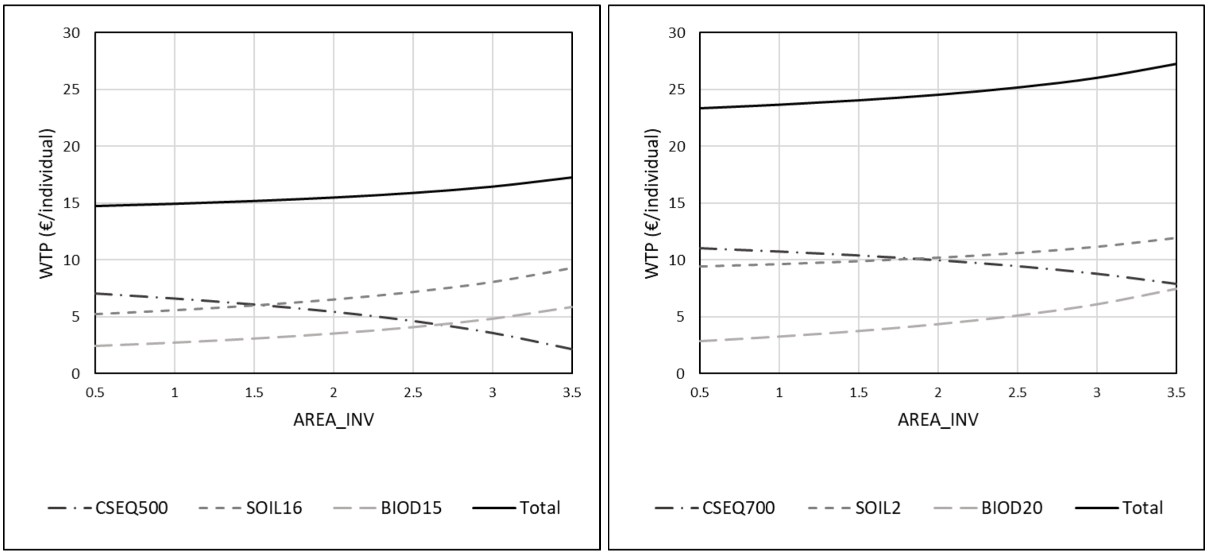
Table 5 Results of the error component random parameter logit models.

	Base Model (no interactions)		Spatial Model 1 (payment interaction)		Spatial Model 2 (payment and ES interactions)	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Parameter mean values						
CSEQ500	1.438 ***	0.128	1.381 ***	0.125	2.624 ***	0.318
CSEQ700	2.474 ***	0.146	2.467 ***	0.139	3.995 ***	0.371
SOIL16	1.527 ***	0.124	1.506 ***	0.125	1.736 ***	0.342
SOIL2	2.476 ***	0.148	2.459 ***	0.152	3.287 ***	0.350
BIOD15	0.850 ***	0.117	0.852 ***	0.117	0.785 *	0.328
BIOD20	1.027 ***	0.130	1.007 ***	0.124	0.892 *	0.361
PAYMENT	-0.250 ***	0.011	-0.339 ***	0.021	-0.355 ***	0.022
ASCSQ	1.700 ***	0.315	0.401	0.691	1.433	0.809
Co-variables						
CSEQ500xAREA_INV					-0.644 ***	0.176
CSEQ700xAREA_INV					-0.790 ***	0.187
SOIL16xAREA_INV					-0.076	0.180
SOIL2xAREA_INV					-0.401 *	0.169
BIOD15xAREA_INV					0.035	0.166
BIOD20xAREA_INV					0.086	0.186
PAYMENTxAREA_INV			0.054 ***	0.008	0.056 ***	0.010
ASCSQXAREA_INV			0.590	0.311	0.100	0.393
Standard deviations						
CSEQ500	0.171	0.514	0.091	0.752	0.058	0.646
CSEQ700	0.745 **	0.238	0.650 *	0.274	0.850 ***	0.253
SOIL16	0.408	0.317	0.412	0.335	0.498	0.309
SOIL2	0.949 ***	0.187	0.820 ***	0.196	0.993 ***	0.221
BIOD15	0.616 **	0.222	0.504	0.271	0.595 *	0.245
BIOD20	1.048 ***	0.159	0.931 ***	0.179	1.040 ***	0.206
PAYMENT	0.250 ***	0.011	0.339 ***	0.021	0.355 ***	0.022
Error component	-4.939 ***	0.359	4.817 ***	0.355	5.163 ***	0.401
Model fit statistics						
Log-likelihood (b)	-2099.54		-2071.67		-2053.50	
Log-likelihood (b0)	-4704.26		-4704.26		-4704.26	
c^2 (p-value)	5209.43	(.00000)	5265.17	(.00000)	5301.52	(.00000)
Pseudo-R^2	0.554		0.560		0.563	
N	4282		4282		4282	
AIC/N	0.988		0.976		0.970	

***;**;* denote significance at 0.1%, 1% and 5% level, respectively.

From the results of Spatial Model 2, the WTP for the ES provided by Andalusian olive growing is estimated using Hanemann (1984). Fig. 1 represents the estimates of WTP for moderate (Fig.

1a) and significant improvements (Fig. 1b) in each and all of the ES considered in function of the AREA_INV index. As shown in these figures, the total WTP (jointly considering the three ES under analysis) increases with increasing values of the index for both moderate and significant improvements. However, when observing the curves for each of the ES separately, different patterns emerge, showing increasing trends for biodiversity and soil conservation, and a decreasing trend for carbon sequestration. These trends show the combined results of two effects: the positive relationship between AREA_INV and the payment parameter, and the negative relationship between AREA_INV and CSEQ500, CSEQ700 and SOIL2. For example, for carbon sequestration, the effect of the interactions of AREA_INV with the parameters (CSEQ500 and CSEQ700) is large enough to prevail over the interaction with the payment. Conversely, in the case of soil conservation, the effect of the interaction with the monetary parameter prevails over the interaction with the ES parameter (especially for moderate improvements), thus showing such a positive trend as a result. In the case of biodiversity, the positive trend seems to be more remarkable for both moderate and significant improvements, especially since no negative interaction term is present.



1a. Moderate improvement *1b. Significant improvement*

Fig. 1. Relationship between the WTP and the AREA_INV Index for moderate and significant improvements in the 3 attributes considered.

All this suggests that the spatial effects depend on the kind of ES considered. This seems to be related to the type of value attached to the service (use and non-use values). Accordingly, in locations near to large olive groves (i.e., associated with a high value of the AREA_INV index), individuals show a preference for the ES with more prominent use value (biodiversity and soil conservation), whereas their WTP for carbon sequestration is lower. On the contrary, those who live farther away from olive grove areas (i.e., associated with a low value of the AREA_INV index) show a higher preference for carbon sequestration than for the ES with higher use value, although on aggregate their WTP for the bundle of the three ES considered is lower. The rationale behind this is that ES with benefits of a significantly local nature (i.e., biodiversity and soil conservation) show greater spatial discounting than those that are primarily perceived at national or global scales (i.e., carbon sequestration). Although different discounting rates for use and non-use values have been pointed out previously (e.g., Hanley et al., 2003, Schaafsma et al., 2012, Jørgensen et al., 2013, Schaafsma et al., 2013), to the authors' knowledge this is the first study to report such a finding for different types of services as well as for scattered environmental sites.

4. Conclusions

Previous literature demonstrates the existence of spatial heterogeneity in the demand for ES, especially by showing spatial discounting (namely, distance decay) and the effect of substitute sites. Our study further contributes by analyzing different ways of modeling these two effects, and applying them to a scattered ecosystem which provides various ES.

The results show that the introduction of any of these spatial indexes significantly improves the fit of the valuation models. As such, they successfully incorporate spatial heterogeneity into the analysis of the demand for ES. Although the results suggest slight differences among indexes, it seems that the discounting factor consisting of the inverse of the distance and the index based on area yield better outcomes. Yet, significant differences are only found for the index combining these two features, which clearly calls for further analysis to confirm the extent to which the use of each—the inverse of the distance and the area-based approach—should be recommended when accounting for spatial heterogeneity in the benefits associated with ES provided by scattered ecosystems.

Besides the use of different spatial indexes, other noteworthy findings relate to the differences in the spatial heterogeneity of benefits derived from the diverse ES provided by the agroecosystem under study. On the one hand, results show the positive relationship between the WTP for biodiversity and soil conservation and the spatial index, meaning that the higher the presence of nearby olive groves, the greater the demand for the provision of these ES. On the other, the results show the opposite relationship for carbon sequestration. These differences may well be related to the different use or non-use values of the ES analyzed, as use values prevail with both biodiversity and soil conservation, whereas for carbon sequestration non-use values are more prominent.

These results have important implications for the design of policies related to the provision of ES in agroecosystems. For carbon sequestration, where there is not a positive relationship between the demand for such ES and the location, the results suggest that the design of the policies should be handled by European institutions, based on their international commitments, as the impact of such policies would be perceived by the wider population at this large scale. On the contrary, for the cases of biodiversity and soil conservation, the results indicate that regional or local governments should implement related policies, as subsequent improvements mainly benefit the local population.

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