CAN GEOCACHING BE AN INDICATOR OF CULTURAL ECOSYSTEM SERVICES? THE CASE OF THE MONTADO SAVANNAH-LIKE LANDSCAPE

ACCEPTED VERSION

Received 19 April 2018; Received in revised form 27 November 2018; Accepted 1 December 2018, Available online 9 January 2019.

Final version - https://doi.org/10.1016/j.ecolind.2018.12.003

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KEYWORDS:
Crowdsourcing databases, land use, spatial analysis, stated and revealed preferences, Iberian Peninsula

Highlights: Please see also the attached file.
Geocachers did not show a priori preferences for different types of land use
After the visit, their stated preferences exposed the appreciation of the *montado* cultural landscape over other forest landscapes; they also expressed preferences for open and aquatic landscapes
Geocaching is a good indicator for cultural ecosystem services
Montado landowners can diversify activities on their properties, decreasing their dependence of provisioning services

Abstract

Cultural Ecosystem Services (CES) are difficult to assess and are seldom considered by land managers. Geocaching, an outdoor game that uses Global Positioning System (GPS) enabled devices to find hidden containers (geocaches) in certain locations, has been seldom used as a data source to assess CES. However, contrary to other crowdsourcing databases, geocaching allows to associate particular experiences to accurate locations. Furthermore, databases generated by geocachers provide an ideal case to compare revealed preferences (the frequency of visits to a specific geocache) with stated preferences (*a posteriori* evaluation of each location). We tested the relevance of geocaching databases as CES indicators using a dataset of 50 818 geocaches spread across continental Portugal, over eight land-use classes, with a focus on the *montado* (a high nature value farmland found in Southwestern Iberian Peninsula). We found that site visitation frequency was related with its availability, showing no revealed preference towards any land use. However, site evaluations by geocachers, measured either through the number of words describing the experience, the number of photos taken, or the number of votes for “favourite geocaches”, showed marked differences in their stated preferences, with higher appreciation for open land uses in general, and *montado* in particular, especially when compared to other forested landscapes. Our results may contribute to the design of regional development and land-use management policies of this threatened landscape, since they show the system’s strong potential as CES provider and, consequently, promoter of diversification of activities.

1. Introduction

Cultural Ecosystem Services (CES) are defined as “the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences” (Millennium Ecosystem Assessment, 2005). This kind of interaction between people and nature implies an emotional connection and the creation of strong ties with the landscapes, nourishing the feeling of being “at home” (Schaich et al., 2010). The value of CES among all Ecosystem Services (ES) is high, either in more industrialized societies, where CES have an expected tendency to increase in importance, or in more traditional communities, where they are often essential for cultural identity and even survival (Milcu et al., 2013). For people in developed countries CES represent one of the strongest incentives to become involved in environmental conservation (Phillips, 1998), and this tendency is also becoming more noticeable in less developed regions (Sodhi et al., 2010).

CES are nowadays considered a fundamental component of the ES frameworks, often influencing more the acquisition and management of the land than traditional commodity production (Bieling, 2004; Plieninger et al., 2012). On the other hand, CES have less potential for mediation by socioeconomic factors, as compared to other ES, which means that, once degraded they are unlikely to be replaced by technical or other means (MA, 2005).

Cultural landscapes are defined as “landscapes with a long history, which evolved slowly and where it took centuries to form a characteristic structure reflecting a harmonious integration of abiotic, biotic and cultural elements” (Antrop, 1997). These landscapes have the peculiarity of having an added value, as compared to more “natural” habitats, since besides the natural value, they hold cultural value, due to the long and complex history of coexistence with man (Schaich et al., 2010). However, cultural landscapes are undergoing rapid transformations across the world, driven by abandonment and rural exodus on the one hand, and intensification of human use on the other (Plieninger et al., 2014).

The Portuguese *montado* is a cultural landscape subject to the same type of rapid transformation, affected by several threats and drivers of change, such as abandonment (Bugalho et al., 2011; Godinho et al., 2016), tree mortality (Costa et al., 2010) overgrazing (Almeida et al., 2015; Gonçalves et al., 2012), mechanised ploughing (Pinto-Correia, Ribeiro, & Sá-Sousa, 2011) or climate change (Correia et al., 2018; López-Tirado et al., 2018; Ogaya and Peñuelas, 2006; Vessella et al., 2017).

Montados are agro-silvo-pastoral systems that resulted from millennia of traditional land use practices on the original Mediterranean woods dominated by cork oaks (*Quercus suber*) and holm oaks (*Quercus ilex* or *Q. rotundifolia*) (Joffre et al., 1988, 1999). These man-modelled ecosystems have a savannah-like aspect (Figure 1) and are characterized by scattered trees, with herbaceous understory and near absence of the shrub layer (Joffre et al., 1999).

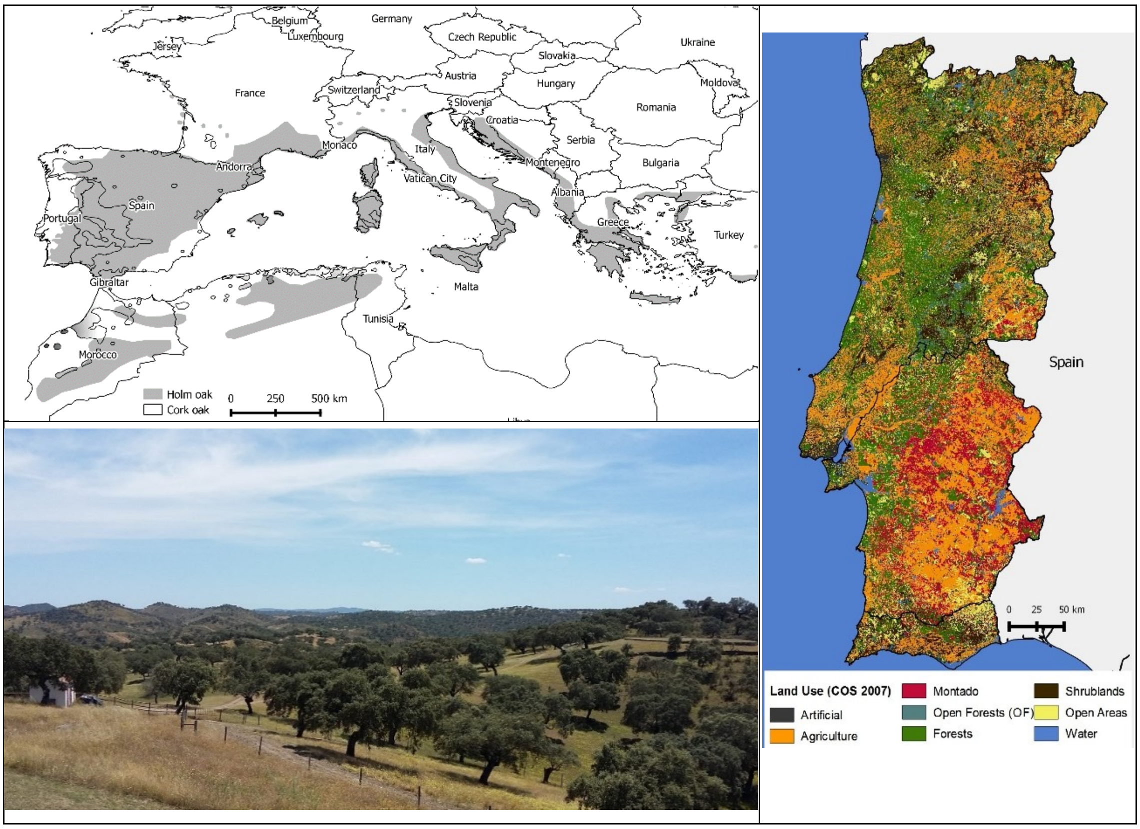

Figure 1 – Up left) distribution of Mediterranean oaks (cork oak and holm oak) adapted from Caudullo et al., 2017; bottom left) *Montado* landscape in southeast Portugal (Herdade da Coitadinha); right) land use map of mainland Portugal (COS – Carta de Uso e Ocupação do Solo- 2007 reclassified to 8 land use classes).

On *montados*, three main rural activities are pursued simultaneously within a single space: harvesting of forest products, livestock husbandry, and agriculture (Blondel, 2006). The largest cork-oak *montado* area in the world is found in southern Portugal (Alentejo region, a district inherently linked to *montado* landscape), where about 90% of the Portuguese distribution of this system is located (Figure 1). Portuguese holm oak *montados* are also more frequent in the Alentejo region and continue into Spain (where they are called *dehesas*), being part of the largest holm oak *montado* landscape in the world (Ribeiro et al., 2010). Although created and permanently managed by man, this ecosystem maintains high biodiversity levels (Blondel, 2006; Bugalho et al., 2011; Carrete and Donazar, 2005; Díaz-Villa et al., 2003; Martins da Silva et al., 2008; Pereira, 2012; Tellería, 2001), and is considered a priority habitat for conservation (Annex I of the European Union Habitats Directive 92/43/CEE) and a High Nature Value Farmland (HNVF) (EEA, 2004).

This multi-use system is responsible for the delivery of many ES, such as, among the regulation and maintenance ES, the protection of soil against erosion by vegetation, or climate regulation (Barredo et al., 2015; Guerra et al., 2016). The most recognised ES is a provision ES, namely the production of cork, an important revenue for Portugal, representing 1.2% of Portuguese exports (APCOR, 2016). Other relevant provisioning services are food products from Alentejo, which lead the Portuguese DOP (Protected Designation of Origin) markets (Tibério and Francisco, 2012). Traditional products include a variety of sheep or goat cheeses, and especially the ham or sausages made from the meat of free-ranging Iberian pigs fed on holm oak acorns. Besides its important market value, these products have an additional cultural value, as the clear connection with the landscape provides them a regional identity. Picking up asparagus or mushrooms (picked up for food by local people for centuries) are also examples of activities that nowadays represent more cultural services than provisioning ones (Molina et al., 2012). Other leisure activities emerged more recently through well-established events associated to this landscape, e.g. the running trail "*Montado* Running" or the mountain biking "*BTT Terras do Montado*". Even the harvesting of the bark of the cork oak tree has a cultural value, since it is a traditional hand-made activity, carried by specialised workers using only a small axe, and transmitted across generations (APCOR, n.d.). People also identify this landscape with traditional music ("Cante Alentejano" was classified as Intangible Cultural Heritage of Humanity in 2014), traditional clothes and language (very strong and peculiar regional accent). Finally, the intrinsic natural characteristics of *montado* potentiates the delivery of CES similar to other natural areas, namely nature-based recreation such as hunting, fishing, birdwatching or geocaching (Belo et al., 2009).

Measuring CES has been one of the most difficult and least accomplished tasks in ES research (Millennium Ecosystem Assessment, 2005), up to today (Daniel et al., 2012; Yoshimura and Hiura, 2017). The intangibility of these services is often considered the reason for their poor appraisal (Hernández-Morcillo et al., 2013; Schaich et al., 2010), and CES are seldom integrated in management plans and reflected in economic indicators (Milcu et al., 2013). This underrepresentation results in biased ES assessments (Hernández-Morcillo et al., 2013) and management planning, preventing the integration of CES into policy measures.

Some researchers defend that CES cannot be split into discrete units for marginal valuation (Abson and Termansen, 2011), and there are suggestions for the use of indicators attributed to particular landscape characteristics which hold several CES (Norton et al., 2012; Plieninger and Bieling, 2012). Participatory mapping (Fagerholm et al., 2012; Plieninger et al., 2013b; Van Berkel and Verburg, 2014) or photo-based methods (Almeida et al., 2014; Oteros-Rozas et al., 2017) are among the methods used to define consensual indicators. More recently, crowdsourcing indicators available in social networks such as Panoramio, Flickr, Facebook, Twitter or Instagram, are becoming popular (Figueroa-Alfaro and Tang, 2017; Gliozzo et al., 2016; Tenerelli et al., 2016; Yoshimura and Hiura, 2017). These indicators are mostly estimated from geotagged photographs voluntarily uploaded by users in social networks in high numbers. Similarly to the social networks mentioned above, geocaching can provide visual and written information through its online platforms, but studies using these data to assess CES are very scarce and, to our knowledge, only related to recreational services (Cord et al., 2015; Mendes et al., 2013; Santos et al., 2014, 2012).

Geocaching is an outdoor game where users (geocachers) use Global Positioning System (GPS) enabled devices to find hidden containers, known as geocaches (or simply caches), and then sign a logbook to record and share the visit with the geocacher community. According to the game rules, each attempt to find a cache must also be registered (logged) on the geocache web-page, on the official geocaching website, by writing the geocacher experience, uploading photos, and voting on favourite caches (see methods for more information on this). The availability of exact locations and additional information, comparatively to other online platforms, is an opportunity to explore the feasibility of using geocachers' logs as CES indicators, since, while playing this game, geocachers can benefit from several bundles of CES, such as aesthetics, bequest, recreation or inspiration for art. Motivation to find a particular geocache can derive from many factors (Cord et al., 2015; O'Hara, 2008; Vartiainen and Tuunanen, 2013), and not all of them are related to the landscape. However, regardless of his(her) motivations, throughout the journey and culminating at the geocache, each geocacher will necessarily experience the landscape; this interaction can be stated in the geocacher's log and become a source of information.

In this study we aim to demonstrate the usefulness of the until now largely unexplored geocaching databases as CES indicators and focused our analysis on the *montado* cultural landscape. With an innovative approach, we used both the number of visits to each geocache and the amount of information stated in the logs (whether text, photos or votes) to evaluate geocachers emotional connection with the different land use classes. First, to detect a potential *a priori* drive towards a particular type of landscape, we compared the frequency of visits to geocaches located in different land uses with their availability. Second, we assessed the stated experience of geocachers at each land use by comparing the number of words, photos or votes per log. We assumed that the time invested in writing or taking pictures (translated into number of words or photos, respectively) should be proportional to the intensity of the emotion felt by geocachers. Given the human preference for open landscapes that allow a view over wide areas (Hartmann and Apaolaza-Ibáñez, 2010; Kaplan, 1987; Mendes et al., 2014), we hypothesized that the savannah-like *montado* should be preferred over closed forest landscapes. We also hypothesized that variables affecting the sense of vastness, such as altitude and landscape heterogeneity, should be influential on the geocachers' experience.

2. Materials and Methods

2.1. Study area

We considered mainland Portugal as our study area, covering a roughly rectangular 89.060 km^2 area in the Western Iberian Peninsula (Figure 1). Higher altitudes occur in the north, reaching 1991m in Serra da Estrela, while through the south of the Tagus River flat plains are dominant. Seashore extends for 850 km, alternating sandy beaches with cliffs. Southern regions are subject to Mediterranean climate, while the north has Atlantic influences (Ferreira, 2000). Mean annual temperature is very mild and ranges from 7.5 ºC to 17.5 ºC (Ferreira, 2000) and the annual solar radiation reaches one of the highest levels in Europe (Joint Research Centre, n.d.).

These topographic and climate characteristics are an invitation to outdoor activities (Santos et al., 2012). As in most Europe and particularly in the last two decades, the demand for outdoor activities and leisure in Portugal shows a growing trend (Roque et al., 2014; Serôdio, 2012), and geocaching is no exception. When this study was conducted circa 35000 geocaches were active in Portugal (“Geopt.org - Portugal Geocaching and Adventure Portal,” n.d.).

2.2. Geocaching data

When finding a geocache, in addition to sign in the logbook hidden in the container, geocachers also can log in the official geocaching website, where anyone can register for free. Many logs simply acknowledge another “found it”, but geocachers are encouraged to share their discovery by posting small texts and photos, building a strong community sense around this recreational activity. Premium members can also vote for favourite caches, leading other geocachers to try to find them afterwards. All geocachers have access to the official website (geocaching.com), where all this information is available.

Geocaching data for this study was collected from www.geopt.org (one of the two Portuguese geocaching forums) on November 22nd, 2016 (full dataset). To build a uniform matrix of comparable data, only the traditional geocaches (see Table 1 for terminology) were kept and geocaches with less than 50 logs were excluded.

Table 1 - Geocaching terminology relevant for the present study.

Term	Description
Geocacher	Person who does geocaching, as opposed to “muggles”, who don’t know the game
Geocache(s)/caches	Hidden container at a specific coordinate[1], which has at minimum a logbook for geocachers to sign. There are 18 types of geocaches. Besides the traditional geocache (see definition below), the other types can involve several locations, being the last one the real cache or, for example, a puzzle that the geocacher must solve in order to obtain the container coordinates. [1]Geocaching has emerged in the year 2000 after the removal of the international degradation of GPS signals (Selective Availability) reducing the error to 10-15 m (http://www.gps.gov).
Owner	Geocacher that creates and places a geocache on the ground for the community.
Traditional cache	This is the original type of geocache and the most straightforward. These geocaches are containers at specific coordinates. The size and contents of the container may vary, but at minimum, all have a logbook. Larger containers may also contain items for trade.

Log	Act of registering a visit to the geocache at the website, even if the geocache was not found. Thus, we used the number of logs as a proxy to the number of visits.
Found/not found	When a geocacher logs a geocache he (she) must register if it was found or not found.
Terrain (TERR)	Physical effort needed to reach a geocache. Provided by the owner of the cache on a scale from 1 (less effort) to 5 (more effort).

2.3. Land use data

In order to analyse the landscape surrounding each geocache we used a land use map (COS – *Carta de Uso e Ocupação do Solo* - 2007) of mainland Portugal (DGT – Direção Geral do Território, 2011) with a minimum mapping unit of 1 ha. This map has a hierarchical classification from level 1 (minimum detail) to level 5 (maximum detail), where classes of higher detail are nested within less detailed classes. For this study, 8 major land use classes were considered: i) Artificial, ii) Agriculture, iii) *Montado*, iv) Open Forests (OF), v) Forests, vi) Shrublands, vii) Open Areas and viii) Water (Figure 1). Some classes are the same as the defined in level 1 of COS 2007, such as Artificial, while others were defined using higher levels of detail (see table in Annex for detailed description of land uses). COS 2007 level 3 legend perfectly matches CORINE Land Cover CLC 2006 level 3 legend, allowing the integration of COS product with the European CORINE program. The same COS level 3 also matches other international mapping initiatives like TBFRA 2000 (UN-ECE/FAO, 2000) and LCCS (Di Gregorio et al., 2016). For the classification of *montado*, all the open forests (canopy cover less than 30%) and agroforests including cork oaks and/or holm oaks were considered. The category “Open forests” (OF) corresponds to agroforests including other species and mixes of species different from those found on the *montado*, such as the pyrenean oak (*Quercus pyrenaica*) and other oaks (*Quercus* sp.), sweet chestnuts (*Castanea sativa*), eucalyptus or pines. We used this category to compare the preferences for *montado* landscapes with other structurally similar, assuming that they are not recognized by Portuguese as having the same cultural value. To extract land use variables, the land use vector file was converted to a raster file with a 50 m resolution using GRASS (Team, 2015). Although there is a temporal mismatch between landscape data (2007) and geocaching data (2016), land uses did not change significantly between those years (Caetano et al., 2018).

Considering the 8 land use classes defined for this study, it is evident the predominance of Agriculture (31%) in Portugal, followed by Forests (24%). Shrublands (14%), Open Areas (10%) and *Montado* (9%) were less represented and some classes (Artificial, OF and Water) covered less than 5% of the land (Figure 1, Table 3).

A 250 m buffer was created around each geocache as a spatial unit to extract land use geospatial variables: i) land use (LU) at the geocache coordinate; ii) dominant land use in the buffer (DLU); iii) variety (VAR), i.e., the number of land use classes in each buffer. Average altitude (ALT) in each buffer was withdrawn from the 90 meter SRTM v4.1 digital terrain model (Jarvis et al., 2008). To minimise spatial autocorrelation some geocaches were excluded from the analysis. This was done by a hierarchical process in GIS, starting by identifying and retaining the non-overlapping geocaches. Then, a grid with 1km squares was superimposed on the overlapping geocaches and we selected the geocache closer to the centroid in each square. Finally, we merged these to the previously retained non-overlapping caches and attained our final subset. All these analysis were performed using QGIS (QGIS Development Team, 2015).

2.4. Data analysis and statistics

Revealed preferences (following the definition by Cord et al. (2015)) of geocachers for each land use were assessed with Pearson's correlation coefficient by taking the number of caches available on each land use and the number of logs (=visits) to these sites. A positive correlation between the number of available caches and the number of logs would reveal that geocachers simply make more visits to land uses where more caches are available, suggesting that the main reason for the decision of the sites to visit is not related to land use.

Stated preferences (again following Cord et al. (2015)) were assessed using a combined approach. In a first step, we considered four variables from the geocaching database expressing distinct attributes of geocacher preferences (Table 2) and those described by absolute values (all except *Log size*) were divided by the number of logs, since the number of logs can be very different among caches. The comparison of these variables, after transformation, between land uses was done using column charts. In a second step, a Principal Component Analysis (PCA) was applied on the four variables and the first axis of the PCA was considered as the new latent variable representing the stated preferences of geocachers. PCA was performed based on the correlation matrix of variables using R version 3.3.2. (R Core Team, 2017). Differences in stated preferences (first axis of the PCA) between land uses were tested with non-parametric tests (Mann-Whitney U tests or Kruskal-Wallis, according to the number of categories), followed by post-hoc tests (with Bonferroni correction), in the case of Kruskall-Wallis. These analyses were performed using the software SPSS (IBM Corp., 2017).

Table 2 - Variables used to measure stated preferences. a – original range of values, b – range of values after transformation.

Variable	*Description*	*Range (final dataset)*	*Transformation*
Photos	Average number of photos taken at each geocache and uploaded in the official website.	0 - 1555 a 0 - 5.97 b	Number of photos divided by the number of logs.
Votes	Average number of votes given by geocachers, for each cache, at the GCVote site. GCVote is an extension for the official geocaching site that enables geocachers to rate the quality of caches. Anyone can register for free at this site and vote for any geocache. Rating scale goes from 1 (poor) to 5 (awesome).	0 – 107 a 0 – 0.338b	Number of GC votes divided by the number of logs.
Favourites	Average number of favourites by cache. For every 10 geocaches found, premium geocachers can choose a favourite.	0 – 567 a 0 – 0.683 b	Number of favourites divided by the number of logs.
Log size	Average size of the log (length of the text written during log in, measured by the number of characters) for each cache.	77 – 1256 a	No transformation.

We further used a Generalized Additive Model (GAM) (Hastie and Tibshirani, 1990) to understand which terrain features may influence geocachers stated preferences. GAM has the advantage over other methods (e.g. Generalized Linear Models), as it allows to model non-linear relationships between all or some explanatory variables and the response variable. GAM was estimated by a quadratic penalised likelihood approach, as implemented in the mgvc package for R (Wood, 2011). Smoothed terms were based on smoothed splines. Four variables potentially related with geocachers connection with the landscape were used as explanatory variables: the dominant land use in each buffer (DLU), the number of land uses present in each buffer (VAR), the mean altitude in each buffer (ALT) and the physical effort needed to reach a geocache (TERR). These four variables were selected because were suspected to have an influence on perceptions of the landscape: DLU and VAR influence preferences, ALT influences the perception of the surroundings and TERR was used to test if a variable non-related to land use could influence preferences.

The first axis of the PCA described in second step was used as the response variable. DLU is a categorical variable, i.e. coded as dummy variable in the analysis, and hence it was not included in the GAM as a smoothed term, i.e., only parametric coefficients were computed for this variable. The *montado* class of the dummy variable was coded as the reference DLU, i.e. when all other DLUs equals zero, so the resulting coefficients of the parametric terms refers to this class. Because the effect of VAR, ALT and TERR can be potentially influenced by DLU, we also included the interaction terms between the three variables and DLU in the model.

3. Results

3.1. Revealed preferences

3.1.1. Full dataset

The full dataset integrated 50818 geocaches, prevailing those located in Artificial (37%), followed by Forests (19%), Agriculture (17%), Shrublands (12%) and Open Areas (8%). All the other LU classes had less than 4% of caches each (Table 3). The number of geocaches in each LU was not proportional to area covered by it, particularly in artificial areas, which have the highest density of geocaches (4.34 caches/km^2), while all the other LUs had less than 1 cache/km^2.

The percentage of geocaches available in each LU type was very similar to the percentage of logs in the correspondent LU (Table 3), also shown by a very high correlation between the number of logs and number of geocaches per land use (0.98 Pearson $p<0.001$), showing that geocachers tend to visit the caches according to their availability, regardless of the land use. The differences between these two percentages are less than 3% in every land use class, with the single exception of Artificial (7.8%), which is the single land use having more visits than expected. Artificial was the most visited land use (44% of logs) followed by Forest (17% of logs), and then by Agriculture, Shrublands, Open Areas, Water, OF and *Montado*, in precisely the same order as for the availability of caches per land use.

Table 3 - Percentage of each land use class on the study area, number and percentage of logs and number, percentage and density (caches/km2) of geocaches from the full dataset in each land use category.

	Land use Area		Cache density	Geocaches		Logs	
Land use	(%)	(Km^2)	(caches/ Km^2)	N	(%)	N	(%)
Artificial	5	4267	4.34	18525	37	3856168	44
Forests	24	21365	0.45	9616	19	1462276	17
Agriculture	31	27870	0.31	8624	17	1210202	14
Shrublands	14	12181	0.48	5897	12	857746	10
Open Areas	10	9214	0.45	4143	8	704786	8
Water	2	1853	0.84	1556	3	288555	3
OF	5	4425	0.41	1834	4	260024	3
Montado	9	8099	0.08	623	1	81099	1
Total	**100**	**89274**	**0.57**	**50818**	**100**	**8720856**	**100**

3.1.2. Final subset

This dataset included 11335 geocaches, mainly distributed by three LU classes: Artificial (27%), Forest (22%) and Agriculture (22%). Shrublands had 12% of the geocaches (1377) and only 2% (207) were in *Montado* (Table 4). Altogether, the remaining LU categories had 15% of the geocaches. The balanced proportion of geocaches in the three main LU categories results from the exclusion of spatially correlated geocaches, particularly in artificial areas, where overlap was more frequent.

Table 4 - Number and percentage of logs and number and percentage of geocaches from the final subset by each land use (LU) and dominant land use (DLU) category.

	LU (at the geocache)				**DLU (for the 250m buffer)**			
	Geocaches		Logs		Geocaches		Logs	
Land use	N	(%)	N	%	N	%	N	%
Artificial	3107	27	761205	34	2210	19	625003	28
Agriculture	2524	22	436638	20	3676	32	624411	28
Forests	2506	22	437662	20	2655	23	457870	20
Shrublands	1377	12	248941	11	1256	11	218681	10
Open Areas	961	9	204838	9	676	6	131454	6
OF	419	4	77607	3	276	2	50965	2
Water	234	2	52100	2	393	3	111860	5
Montado	207	2	32339	1	193	2	31086	1
Total	**11335**	**100**	**2251330**	**100**	**11335**	**100**	**2251330**	**100**

When considering the dominant land use (DLU) around each cache (250 m buffer) the distribution of caches per class changed slightly (Table 4). Geocaches surrounded mostly by Agriculture became the most frequent (32%), followed by Forests (23%), Artificial (20%), Shrublands (11%) and Open Areas (6%). All the remaining DLUs were present in 8% of the buffers with the *Montado* representing only 2% (193 caches).

Geocaches with Agriculture, Forests or Artificial DLU are the most visited, in similar proportions (20-28%) of the logs, while the remaining land uses are visited according to the availability of caches. Thus, for our final dataset, although the order of available caches per DLU changed, the correlation between available geocaches and the number of logs per DLU was still very high (Pearson 0.94; $p<0.001$).

3.2. Stated preferences

The four variables considered exposed the preference of geocachers by open and vast land uses, particularly Open Areas, Water and Shrublands (Figure 2). More photos were taken, and more favourites were chosen at Water sites while Open Areas were the land use where geocachers attributed more votes and wrote longer texts. Shrublands were the second DLU about which geocachers wrote longer texts and the third where they took more photos and voted more both for Favourites and Votes. Considering forested land uses (Forests, *Montado* and

Open Forests) preferences also go for more open habitats, namely for the *Montado*, which was the second DLU most voted. Finally, a third group of DLUs includes the most human-transformed landscapes (Artificial and Agriculture), which were always the less preferred for any of the variables considered.

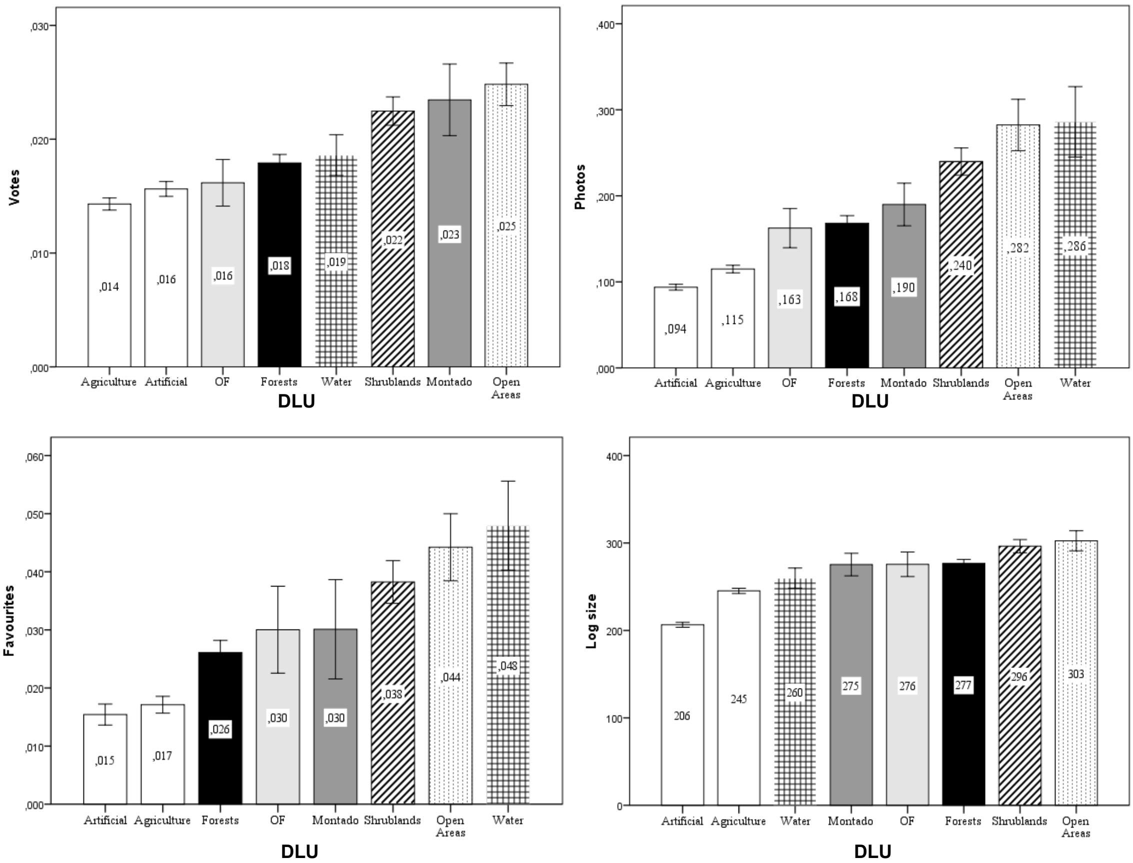

Figure 2 – Average values (columns) in each DLU for the four variables considered to assess the stated preferences: Photos, Votes, Favourites and log size. Error bars: 95% confidence interval.

The first PCA axis (Comp1) explained 49% of the variance and the second (Comp2) 24% (Table 5).

Table 5 - Factor loadings for Comp1 and Comp2 derived from the principal component analysis (PCA) to show revealed preferences of geocacher for land uses.

	Comp1	Comp2
Photos	0.584	-0.122
Votes	0.325	-0.861
Favourites	0.557	0.262
Log size	0.492	0.418
Eigenvalues	1.403	0.979
Variance explained (%)	49.2	24.0
Variance accumulated (%)	49.2	73.2

The number of photos, log size and the number of favourites were the variables contributing the most for Comp1. All variables had positive loadings on the first PCA component. Given this, we assumed that this component can be interpreted as a stated preferences gradient with higher values meaning a higher stated preference for a cache.

The first two PCA components are shown in Figure 3, where we also identified the three groups of DLU previously suggested from the less preferred to the most preferred: i) Human-altered - Artificial and Agriculture land uses, the group with lower stated preferences; ii) Forested - Forests, OF and *Montado*, with intermediate stated preferences, and finally, iii) Open landscapes (Water, Shrublands and Open Areas), with the highest stated preferences. The Forested land use closer to the Open landscapes cluster is the *Montado*.

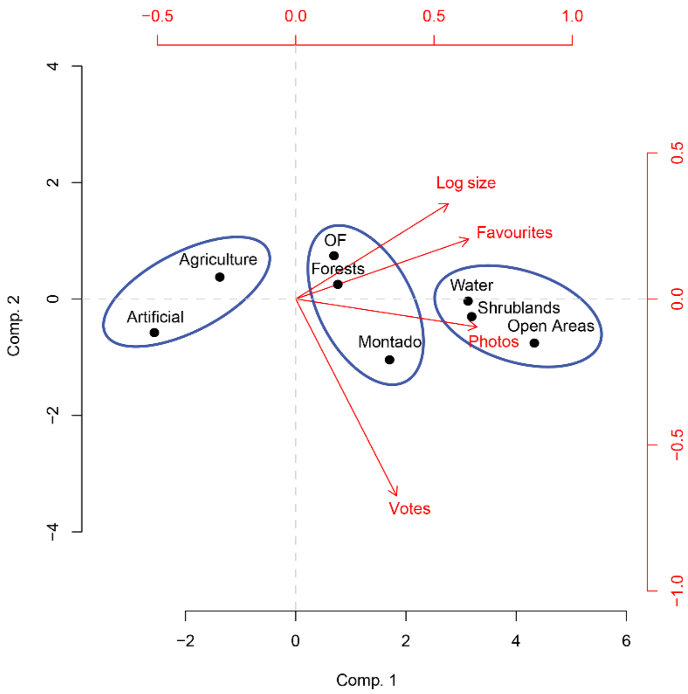

Figure 3 - Biplot of the first two components of PCA (Comp1 and Comp2; explaining 73% of total variance) that represents the factor loadings of stated preferences variables (red labels, arrows and axis) and the mean scores for the categories of Land uses (black labels, dots and axis).

3.2.1. Forested land uses (*Montado*, OF, Forests)

Within the forested land uses significant differences were found (Kruskal-Wallis test, $p<0.05$) when considering the new latent variable representative of the stated preferences, with *Montado* having the highest Comp1 value (Figure 3). Post hoc tests revealed significant differences between *Montado* and Forests ($p=0.001$) and between *Montado* and OF ($p=0.030$). No differences were found between Forests and Open Forests.

3.2.2. Factors affecting the stated preferences

The GAM parametric coefficients reveal that, with the exception of Open Areas, geocachers tend to prefer areas dominated by *Montado* more than any other DLU class, as shown by the negative sign of the coefficients (Table 6). These differences are significant for the human-altered land uses, Forests and OF, but not for the open landscape uses (Water, Shrublands and Open Areas).

Table 6 - Summary of GAM parametric terms (p-value interval codes: * <0.001, ** < 0.01, * < 0.05, <0.1).**

GAM terms	Estimate	Std. Error	t value	p-value
(Intercept)	0.288	0.092	3.142	0.002 **
DLUArtificial	-0.694	0.099	-7.008	2.56e-12 ***
DLUAgriculture	-0.455	0.094	-4.831	1.38e-06 ***
DLUOpen Areas	0.030	0.105	0.289	0.772
DLUShrublands	-0.095	0.100	-0.948	0.343
DLUOF	-0.242	0.123	-1.969	0.049 *
DLUForests	-0.265	0.095	-2.806	0.005 **
DLUWater	-0.041	0.142	-0.287	0.774

Besides DLU, stated preferences of geocachers were also influenced by ALT, TERR and VAR as revealed by GAM (R^2 = 0.38). Overall, geocachers preferred places more difficult to reach (higher TERR values) and located at higher altitudes (Figure 4a). The influence of TERR is consistent across the DLUs, as shown by the significance of smoothed terms (Table 7). The influence of ALT is not as consistent, and it is not statistically significant for OF and water. The influence of VAR is only statistically significant in areas dominated by open landscape uses (Water, Shrublands and Open Areas); in these landscapes geocachers prefer less variety of land uses (Table 7). Nevertheless, this influence is not as clear as for ALT, which means that the preferences of geocachers are less strongly influenced by variety of land uses (Figure 4b).

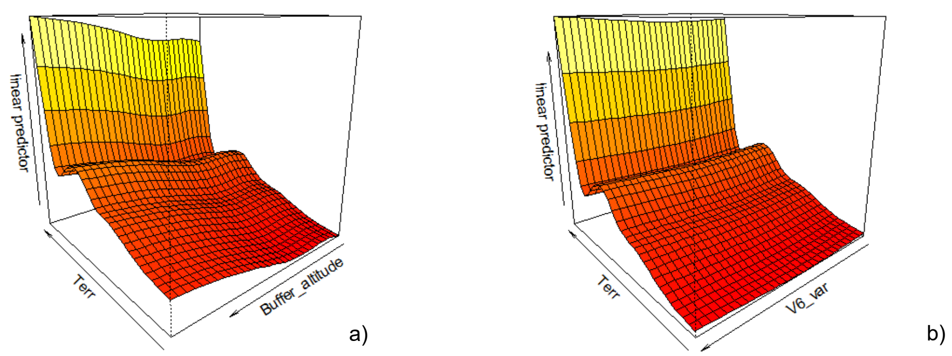

Figure 4 – a) and b) 3-dimensional plots representing the joint effect of TERR with ALT and TERR with VAR.

Table 7 - — Summary of GAM smoothed terms and their approximate significance (edf - estimated degrees of freedom; Ref. df - degrees of freedom for reference distributions; F – F-statistics; p-value interval codes: * <0.001, ** < 0.01, * < 0.05, . <0.1).**

GAM terms	Edf	Ref. df	F	p-value
Interaction TERR x DLU				
s(TERR):DLUMontado	1.997	2.539	11.813	1.22E-06 ***
s(TERR):DLUArtificial	2.506	3.131	15.995	1.44E-10 ***
s(TERR):DLUAgriculture	6.920	6.996	47.123	< 2e-16 ***
s(TERR):DLUOpen Areas	4.107	5.025	189.924	< 2e-16 ***
s(TERR):DLUShrublands	5.244	6.090	181.376	< 2e-16 ***
s(TERR):DLUOF	3.131	3.908	29.057	< 2e-16 ***
s(TERR):DLUForests	6.907	6.995	118.763	< 2e-16 ***
s(TERR):DLUWater	4.079	4.979	121.313	< 2e-16 ***
Interaction VAR x DLU				
s(VAR):DLUMontado	1.000	1.000	0.003	0.954
s(VAR):DLUArtificial	1.000	1.000	2.200	0.138
s(VAR):DLUAgriculture	1.875	2.350	0.896	0.364
s(VAR):DLUOpen Areas	3.572	4.050	8.839	0.000 ***
s(VAR):DLUShrublands	1.060	1.117	8.396	0.003 **
s(VAR):DLUOF	1.584	1.964	0.721	0.522
s(VAR):DLUForests	1.000	1.000	0.625	0.429
s(VAR):DLUWater	4.557	4.890	6.632	0.000 ***
Interaction ALT x DLU				
s(ALT):DLUMontado	1.000	1.000	4.968	0.026 *
s(ALT):DLUArtificial	3.340	3.735	1.718	0.087 .
s(ALT):DLUAgriculture	2.978	3.469	2.273	0.062 .
DLUOpen Areas	4.592	4.912	19.075	< 2e-16 ***
s(ALT):DLUShrublands	1.887	2.363	2.750	0.053 .
s(ALT):DLUOF	2.596	3.110	1.293	0.271
s(ALT):DLUForests	3.298	3.958	7.680	5.12E-06 ***
s(ALT):DLUWater	1.000	1.000	0.023	0.879

4. Discussion

Our results indicate that overall there is no preference for any land use when geocachers plan their visit, suggesting that playing the game is their main motivation. However, stated preferences show that geocachers appreciate more open land uses, exposing the potential of these crowdsourcing data as CES indicators.

4.1. Revealed *vs* stated preferences

Geocache owners hid them in every land use, with the highest density in Artificial areas and in regions with higher population densities. A relation between cache density and urban areas has already been shown, although with preference for green spaces (Cord et al., 2015; Santos et al., 2012). Probably, as in other countries, owners place caches near their residence, although choosing places with elements that can attract geocachers (Cord et al., 2015).

The frequency of visits by geocachers to a site was clearly related to cache availability, which means that they did not choose *a priori* any LU. Motivations to do geocaching seem to be more related to ludic aspects of the game such as the will to collect or the challenge of being the first one discovering a cache (O'Hara, 2008). Although discovering new places or walking outdoors can also motivate geocachers (O'Hara, 2008), previous studies already showed that geocachers usually do not move far from their own municipality (Cord et al., 2015; Santos et al., 2012).

The evidence that geocachers do not show *a priori* preferences for any LU can be viewed as a "natural experiment" when their stated preferences are assessed after the visit. In line with previous studies on landscape appreciation by humans (Hartmann and Apaolaza-Ibáñez, 2010; Kaplan, 1987; Williams and Cary, 2002, 2001), our study showed that in Portugal geocachers prefer the more open land uses and higher places, a preference that may be explained by sense of vastness at the geocache site; when at lower altitudes, and particularly in the case of forested land uses, trees reduce the visual horizon. Geocachers also stated preference for places with water, another common feature of human nature (Petrova et al., 2015; Tieskens et al., 2018)

Terrain difficulty was relevant for geocachers; regardless of the land use they showed preference for sites more difficult to reach. The challenge is one important motivation for geocachers, both from the individual and social point of view (O'Hara, 2008). Geocachers that log at caches more difficult to reach attain a personal achievement and at the same time increase their reputation in the community. A general preference for less fragmented areas (fewer land uses within each buffer) although not as strong, has also been identified. More fragmented areas lessen the sensation of vastness and the sense of control of the landscape (de Val et al., 2006), which is in accordance with the preference for more open landscapes.

4.2. The *montado* landscape

Although the *montado* is not the preferred land use when compared to open landscapes, according to stated preferences, when associated with higher altitudes and terrain difficulty becomes as preferred as those open land uses. It is also the preferred among land uses that have trees. Human preference for savannah-like landscapes has been referred in many studies (Falk and Balling, 2010; Hartmann and Apaolaza-Ibáñez, 2010; Williams and Cary, 2002). The innate preference for open landscapes was suggested by the National Research Council (1986) as an evolutionary advantage for hunters and gatherers living on savannahs, at the time when the hominid brain was increasing in size. According to these authors, these landscapes provide the best shelter, hunting and disease-free environments for hominids. The possibility to see potential predators and prey without being seen (Appleton, 1975), or to easily move through the landscape, is also advantageous (Kaplan, 1991). In spite of the appeal of the savannah hypothesis (Dart, 1925), it is also evident that this preference can, and typically is, modified through personal experience and enculturation (Falk and Balling, 2010; Svobodova et al., 2011). People would tend to prefer more familiar land uses as they grow up, and it would be expected that people that live near a particular land use would have a higher preference for that land use as compared to the others. This could not be assessed in our study because geocache databases do not provide personal details of the geocachers. However, the *montado* landscape covers one of the less populated regions of Portugal (only 7,3% of the population lives in Alentejo (PORDATA and INE, n.d.)), and the proportion of geocachers that was born and raised in Alentejo is expectedly small. Most of the Portuguese population lives near the coast, where artificial, agricultural and forest plantations are the dominant land uses, and so it is probable that most of the positive appreciations of *montado* have been stated by geocachers that do not live surrounded by this landscape.

The preference for the *montado,* comparable to that for the open landscapes, can be explained by the presence of scattered trees, considered an element of appreciation of landscapes (Cook and Cable, 1995; Kaplan et al., 1989; Kaplan and Kaplan, 1989; Ruddell and Hammitt, W., 1987; Williams and Cary, 2002). However, and very interestingly, the other types of open forests (OF) that may be found in Portugal, which are also open, savannah-like landscapes with scattered trees, are not as appreciated by geocachers as the *montado*. One of the factors that can explain this preference is the spreading shape of the canopies, which is characteristic of evergreen oaks (cork and holm oaks). In effect, the other open forest types have different tree species, such as eucalyptus, pine trees or other conifers with more columnar canopy formats, or broadleaf deciduous trees, such as the sweet chestnut or the Pyrenean oak, which are more rounded in shape. An aesthetic, emotional and physiological preference for spreading canopies, as compared to columnar or rounded canopies, was found previously, with people feeling happier when viewing spreading trees compared to other tree formats (Lohr and Pearson-Mims, 2006), this being consistent with the savannah hypothesis.

Another explanation for the preference for *montado* could be the typical presence of free-ranging livestock in this landscape, but we cannot confirm if it occurred by the time geocachers visited the caches. Although the general interest of human beings for life is acknowledged, the aesthetic and emotional value that the animals represent remains rarely discussed (Parsons, 2007).

Finally, this preference can be attributed to the branding of this landscape, already considered a national trademark. The name *montado* is the brand for several food products, from sausages to wine, cork products such as wallets or footware, and even hospitality and tourism, being representative of the *Alentejo* region.

4.3. Geocaching as a crowdsourcing indicator for CES assessment

The value of a landscape to humans is not easy to quantify since many of the services delivered are not products traded on markets. Some services, such as ecotourism or recreation, can only be valued by monetary revealed preferences techniques, such as travel cost methods or hedonic pricing. However, most CES can only be valued by stated preferences methods, where people are asked about their preferences in face of hypothetical changes of the landscape.

These economic methods have been criticized since revealed preference based on monetary valuation is dependent on consumers' sovereignty and not on ecological conditions (Kumar and Kumar, 2008; Milcu et al., 2013), and stated preferences monetary valuation (such as Contingent valuation or Choice Experiments) are not real situations and the money people state be willing to pay is not real (Spash, 2007). Given the problems associated with monetary valuation, many authors increasingly focus on non-economic methods (Buchel and Frantzeskaki, 2015; Edwards et al., 2012; Fagerholm et al., 2012; Hermelingmeier and Nicholas, 2017; Palomo et al., 2013; Plieninger et al., 2013a, 2013b; Sherren et al., 2010; Williams and Cary, 2002, 2001). In recent years, crowdsourcing indicators are becoming popular (Figueroa-Alfaro and Tang, 2017; Gliozzo et al., 2016; Tenerelli et al., 2016; Yoshimura and Hiura, 2017) given the high number of photographs, the easiness to obtain them and the geographical location they provide. Most studies use the number of photographs taken from a particular site as a proxy for the intensity of the respective CES (Martínez-Pastur et al., 2016; Tenerelli et al., 2016).

Geocaching delivers large numbers of photographs available online, and thus can be a good crowdsourcing indicator of CES. As compared to the other user generated contents, geocaching is certainly less known and maybe this is the reason why it is still rarely used as an ES indicator. Nevertheless, the main difference between geocaching and the other user generated contents is that it does not assume that people go to a place attracted by landscape attributes, but rather motivated by the activity itself (which was corroborated in this study). In addition, all participants go to the same specific point where the cache is located rather than being scattered through the landscape. This provides the opportunity to compare information stated by people exactly at the same location, overcoming an often referred problem, which is the error in geotagged photos of other social networks (Tenerelli et al., 2016; Yoshimura and Hiura, 2017).

Besides the number of photos taken, other parameters were chosen to evaluate geocachers perceptions about the landscape, such as the number of votes and their scores. These stated preferences have the advantage of using the same scale for all practitioners. However, one of the most promising parameters is the people's writings in the log. Although not explored in this study, the text contents may contain very relevant information about the landscape and about the geocachers' emotional state. Also out of the scope of this study, but with similar information potential and deserving to be further explored, is the description of the cache itself made by the owner and whose information is generally quite extensive and revealing of the choice of location (Mendes et al., 2014).

Besides not addressing the information on the text and photo contents, this study has other limitations and it should be considered as a first approach to the use of geocaching to assess CES. To actually understand the feelings of geocachers when at a particular place, further work is needed. For instance, text mining and sentiment analysis, by revealing the emotional polarity of the texts written in the log and the landscape features most times referred (Bermingham et al., 2009; Li and Wu, 2010), would reveal much about connection of geocachers with the landscape. Nevertheless, Fartoukh et al. (2012) found a significant correlation between the number of words and positive emotions in texts written by children with different ages, providing strength to our working hypothesis. Furthermore, the factor loadings of Photos, Log size and Favourites on the first axis of the PCA (Figure 3) are positive and similar, suggesting that long texts are used to describe favourite places. In the same way, as suggested above, the number of photos of a particular landscape is probably positively correlated to a positive emotion but only by analysing the content of the photographs we could understand which are the landscape attributes most captured by geocachers and, consequently their actual preferences (Figueroa-Alfaro and Tang, 2017; Martínez-Pastur et al., 2016).

4.4. Key Insights and Policy Implications

This study reveals that the *montado* is a landscape valued by geocachers, and this may apply to other social groups. *Montado* ecosystem has therefore the potential to provide more recreational and cultural services that what has been acknowledged thus far, since ES for the *montado* remain somewhat poorly studied (Leal et al., 2018)

The *montado* faces several threats, some of which are global and common to many ecosystems, such as climate change and increased aridity, with the aggravating factor that almost all the holm (about 99.4%) and cork (about 93%) oak forests are located in areas of high susceptibility to desertification (Dias et al., 2013). Other threats are more specific of the montado, such as diseases affecting cork oaks, abandonment or poor management techniques, all of which exacerbated by the dependence of this landscape on the production of cork.

Diversification of forestry products and services is one of the strategic objectives for the forest in the National Strategy for Climate Adaptation (Dias et al., 2013), following the Commission *White Paper on Adapting to Climate Change – Towards a European Framework for Action* (2009) and the *EU Strategy on Adaptation to Climate Change* (2013). Several municipalities within the *montado* range already developed strategies for mitigation and adaptation to climate change, including non-structural measures such as information dissemination, economic incentives to reduce vulnerabilities and awareness for adaptation (and against maladaptation), and economic instruments (such as environmental markets).

Although these landscapes have a high potential to expand the supply of ES as a response to economic incentives (Bugalho et al. 2017), there is a low uptake of agri-environmental measures for the *montado*-covered areas, mostly due to low compensation values from the landowners perspective (Santos et al., 2015). However, some landowners and managers already regard cultural services as a potential source of income. Their numbers should increase as the recreational or inspirational potential of these landscapes becomes better known.

5. Conclusions

In this study, we demonstrated that the information provided online by geocachers can be used to ascertain landscape preferences. Along with expected results, such as the preference for landscapes with water, we have gained insights on the determinants that may explain the attraction for *montado* savannah-like landscapes and this information may support the design of regional development and land-use management policies. Allowing the comparison of *a priori* preferences (choice of place to visit) with the stated preferences (a posteriori site evaluation) is one of the great advantages of using geocaching-produced data, as it allows to assess the effects of any a priori preference for a region or landscape. Other advantage of geocaching data is the reduced error in caches location as compared to other crowdsourcing data and a more numerous and diversified data. On the other hand, when geocachers write their opinions in the logs they are not feeling pressured by anyone, as sometimes happens with face-to-face interviews and other kinds of methods which requires the intervention of a mediator. Our results also indicate that the *montado* has a strong potential as CES provider and, consequently, as a promoter of this landscape diversification, reducing the risks of being highly dependent on provision services. Given the considerable increase of tourism in Portugal, representing 7% of the Portuguese GDP (PORDATA, 2017), this would be of interest and compatible with activities already implemented and, if properly conducted, environmentally sustainable.

Acknowledgements

The lead author was supported by the OPERA Project (Operational Potential of Ecosystem Research Applications) European Union Seventh Framework Programme (FP7-ENV.2012.6.2-1) under grant agreement n° 308393. Pedro Segurado was supported by a contract funded by the Fundação para a Ciência e Tecnologia (FCT) under the IF Researcher Programme (IF/01304/2015). Ricardo N. Mendes was supported by CICS.NOVA - Interdisciplinary Centre of Social Sciences of the Universidade Nova de Lisboa (UID/SOC/04647/2013) and Margarida Santos-Reis and Rui Rebelo by cE3c – Centre for Ecology, Evolution and Environmental Changes (UID/BIA/00329/2013), both units with the financial support of FCT/MCTES through National funds.

Annex

This study	COS description	Agregation
Artificial	Artificial surfaces	level 1
Water	Wetlands	level 1
	Water bodies	level 1
Agriculture	Arable land	level 2
	Permanent crops	level 2
	Pastures	level 2
	Annual crops associated with permanent crops	level 3
	Complex cultivation patterns	level 3
	Land principally occupied by agriculture, with significant areas of natural vegetation	level 3
Montado	Cork or holm oaks agro-forestry with non-irrigated crops	level 5
	Cork or holm oaks agro-forestry with irrigated crops	level 5
	Cork or holm oaks agro-forestry with pastures	level 5
	Cork or holm oaks agro-forestry with permanent crops	level 5
	Cork or holm oak open forests	level 5
	Cork or holm oak open forests with other broadleaf trees	level 5
	Cork or holm oak open forests with evergreen trees	level 5
Forests	Forests	level 2
Open Forests (OF)	Other agro-forests with non-irrigated crops	level 5
	Other agro-forests with irrigated crops	level 5
	Other agro-forests with pastures	level 5
	Other agro-forests with permanent crops	level 5
	Broadleaf open forests	level 5
	Pure or mixed evergreen open forests	level 5
	Evergreen and broadleaf open forests	level 5
Open Areas	Natural grasslands	level 3
	Clear cuts and new plantings	Level 4
	Tree nurseries	Level 4
	Firebreaks	Level 4
	Open spaces with little or no vegetation	Level 2
Water	Wetlands	Level 2
	Water bodies	Level 2

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