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Research paper

An indicator-based approach to analyse the effects of non-native tree species on multiple cultural ecosystem services

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ABSTRACT

Limitations in the assessment of cultural ecosystem services through quantifiable approaches have constrained our knowledge of how these services can be altered by drivers of global change, such as non-native tree species. Here, we address this caveat by evaluating the effects of non-native tree species, in comparison to native ones, on several categories of cultural services, i.e., recreation and ecotourism, aesthetics, inspiration, and cultural heritage. We propose an indicator-based approach that includes the use of a meta-analysis statistics, the odds ratio, to evaluate photographic, internet and catalogue data, and to infer on the effects of non-native trees on cultural services. We apply our approach to the Iberian Peninsula, exploring potential environmental and socio-economic predictors of non-native tree effects across NUTS-2 administrative regions. Overall, non-native tree effects differed among categories of cultural services and varied with the data type. Non-native trees increased recreation and ecotourism services, when considering data from official tourism entities, but not from nature route users. Data from inventories of urban parks and catalogues of ornamental plant dealers suggested that non-native trees decreased aesthetics services, particularly in Spain, but not in Portugal. Non-native trees also increased cultural heritage services, but no significant effects were observed on inspiration services. Overall, non-native trees showed higher increases in cultural services across regions with lower levels of development (in terms of income, employment and education) and life satisfaction. We suggest that management should emphasise awareness on non-native trees, including the risks involved in promoting the expansion of potentially invasive species. Efforts to raise awareness should prioritise official tourism entities and ornamental plant dealers, with a special focus on less developed regions. Our proposed approach represents a pioneer assessment of the relations between non-native trees and cultural ecosystem services, supporting strategic management in Iberia. The focus on widely available data sources enables reproducibility and application in assessments worldwide.

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1. Introduction

The growing recognition of nature's contributions to human well-being has fostered research on ecosystem services (Blicharska et al., 2017; MEA 2005; Schröter et al., 2016). Besides provisioning (e.g., drinking water, secure food) and regulating (e.g., hazard mitigation, pollination) services, ecosystems also provide cultural services. The *Millennium Ecosystem Assessment* (MEA 2005; p. 40) defines cultural ecosystem services as the "*nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences"*, including inspiration and cultural heritage values (see also Chan et al., 2012; Fish et al., 2016).

Cultural ecosystem services are relevant in various governance contexts, such as land tenure and management, recreation revenues, and human identity and traditions (Carruthers et al., 2011; Plieninger and Bieling 2012). However, difficulties in the assessment of cultural services, arising mostly from their subjectivity and difficult quantification, have hampered their consideration in decision-making (Chan et al., 2012; Fish et al., 2016; Schröter et al., 2016). Examples of emerging approaches to asses cultural services include: the use of historical records and vegetation mapping to obtain quality indices of landscape aesthetics or heritage (e.g., Tengberg et al., 2012); public opinion polls to identify cultural benefits (e.g., Poe et al., 2016); monetary evaluations of ecosystem properties (e.g., van Berkel and Verburg 2014); and consideration of ecosystem features per se as surrogates of cultural services (e.g., birds, coloured flowers; Soliveres et al., 2016). The use of social media, namely photographic and (other) internet information, has also been suggested as a promising approach (e.g., Oteros-Rozas et al., 2017). Coupled with traditional data sources (e.g., land cover), social media data can offer novel insights on human-nature relations (Figueroa-Alfaro and Tang 2017).

Understanding how cultural services may be changed by drivers of global change, such as the occurrence of non-native tree species, is a challenge requiring attention (Hernández-Morcillo et al., 2013; Milcu et al., 2013; Oteros-Rozas et al., 2017). Non-native trees can be defined as tree species that were introduced by humans to new geographic areas (Richardson and Rejmánek 2011). Non-native trees have been introduced for various purposes aiming to increase ecosystem services, mainly wood production, landscape restoration, and ornamental values (Dickie et al., 2014; Kueffer and Kull 2017; Kull et al., 2011). They provide key resources worldwide, supporting daily basic needs of local communities and economic revenue in forestry and agro-forestry systems (Kull et al., 2011; Vaz et al., 2017a).

Several environmental factors influence the performance of non-native trees in introduced areas (Brundu and Richardson 2016; Carruthers et al., 2011). Climate and land cover, among others, shape habitat conditions that may constrain or promote the occurrence and performance of non-native trees (Richardson et al., 2014; van Wilgen et al., 2011; Vicente et al., 2016), and thus their effects on ecosystem services. For example, the aesthetic value of non-native trees is influenced by their occurrence, abundance and physiology (Kueffer and Kull 2017), which are inevitably determined by environmental conditions (Richardson et al., 2014; Vicente et al., 2016).

Non-native trees can also decrease ecosystem services and even promote ecosystem disservices, especially when spreading outside plantations, becoming invasive and competing with service-provider native species (Brundu and Richardson 2016; Pyšek et al., 2012; Krumm and Vítková 2016; Vilà and Hulme 2017). Many studies already highlighted that non-native species can reduce provisioning and regulating services, such as water provision, soil stabilization, and wildfire regulation (e.g., Castro-Díez et al., 2014a; Carruthers et al., 2011; Dickie et al., 2014; Pyšek et al., 2012). However, compared to other types of ecosystem services, their effects on cultural services have seldom been investigated (Kueffer and Kull 2017; Vilà and Hulme 2017).

It has been suggested that the cultural value of non-native trees depends on visual attributes, such as landscape monotony and homogenisation (e.g., large plantations or invasions) or "out-of-normal" and "exotic" features (e.g., large leaves, colourful flowers; Kueffer and Kull 2017). Non-native trees can also be valued as historical or scientific assets (e.g., from overseas expeditions; Carruthers et al., 2011; Crews 2003). Most research so far has focused on narratives related to heritage, folklore and tradition (e.g., Carruthers et al., 2011; Kueffer and Kull 2017; Kull et al., 2011). Examples include the use of non-native species as monumental trees in Italy (Asciuto et al., 2015); the adoption of *Eucalyptus* species in South Africa, *Pinus* species in New Zealand, and *Rhamnus* and *Salix* species in Australia for leisure activities (Dickie et al., 2014); or the use of *Acacia* species in South Africa for cultural ceremonies (Kull et al., 2011).

The cultural value of non-native trees may depend on socio-economic (e.g., education, market values) and welfare factors that influence human perceptions, judgements and attitudes towards these species (Brundu and Richardson 2016; Krumm and Vítková 2016). For instance, wealthy countries are more likely to foster the trade and maintenance of non-natives (also Humair et al., 2015; Vilà and Pujadas 2001), and thus their effects on cultural services. Education and awareness also influence the way non-native species and respective cultural services are perceived by people (Carruthers et al., 2011; Kueffer and Kull 2017). Understanding the relations between non-native trees and cultural services across relevant environmental and socio-economic factors could contribute to better management (Dickie et al., 2014; Vaz et al., 2017a). Specifically, it could help in deliberating risks and opportunities associated to non-native trees (Carruthers et al., 2011; Kueffer and Kull 2017), while converging with sustainability goals and human well-being (Ghosh and Traverse 2005; Vaz et al., 2017b).

The Iberian Peninsula (Portugal and Spain) has been the target of many introductions of non-native tree species. Some of these species are restricted to urban areas as ornamentals e.g., *Jacaranda mimosifolia* D.Don, but many others, such as *Ailanthus altissima* (Mill.) Swingle (tree of heaven), *Eucalyptus globulus* Labill. (tasmanian blue gum), *Acacia longifolia* (Andrews) Willd. (long-leaved wattle), *Pinus radiata* D. Don (monterey pine), *Pseudotsuga menziesii* (Mirb.) Franco (douglas fir), *Quercus rubra* L. (red oak) and *Robinia pseudoacacia* L. (black locust), have become widespread (e.g., Castro-Díez et al., 2014a; Sanz Elorza et al., 2004; Vicente et al., 2016). Concern on non-native tree species (either planted, naturalised or invasive) is growing, as they can compete with native biodiversity and change provisioning and regulating services (e.g., related to soil regulation and water provision; Castro-Díez et al. 2014b; Godoy et al., 2010; Morais et al., 2017; Vicente et al., 2016). However, to our knowledge, no studies have assessed how non-native tree species affect cultural services in Iberia.

In this study, we propose an indicator-based approach to assess the effects of non-native trees on recreation and ecotourism, aesthetics, inspiration and cultural heritage (MEA 2005). The approach includes the use of a meta-analysis statistics, the odds ratio, to evaluate photographic, internet and catalogue data considered as relevant to infer on the effects of non-native trees in cultural ecosystem services. We apply the proposed approach at the regional level in the Iberian Peninsula (i.e., NUTS-2 administrative regions) and compare the obtained results between countries (i.e., Portugal versus Spain). Then, we evaluate if the regional variations of non-native tree effects change along predictors related to land cover and management, socio-economy, human well-being, and climate. Finally, we provide considerations for the management of non-native trees in Iberia, and discuss the potential applicability of our approach to other contexts and social-ecological challenges.

Table 1
Categories of cultural ecosystem services considered, with respective data types and rationale. The number of data sources (n) considered for each data type of cultural ecosystem services is shown. The table also describes the components (A-D: equations (1)–(4)) of the indicator proposed for evaluating non-native tree effects on cultural services (see Section 2.2. Data analyses).

Data types	Rationale	Components of the indicator			
		Amount of non-native trees in the service (A)	*Amount of native trees in the service (B)*	*Amount of non-native trees in the region (C)*	*Amount of native trees in the region (D)*
Recreation and ecotourism					
Tourism information (n = 21)	Photographs from tourism websites have the potential to attract tourists	Number of photographs dominated by non-native trees	Number of photographs dominated by native trees	Cover of non-native trees in the region	Cover of native trees the region
Nature routes (n = 161)	Geo-referenced nature routes shared with the public translate society preferences for recreation	Number of photographs dominated by non-native trees	Number of photographs dominated by native trees	Cover of non-native trees in the region	Cover of native trees in the region
Aesthetics					
Catalogues of plant dealers (n = 28)	Tree species offered by plant dealers are appreciated mostly by ornamental values	Number of non-native tree species offered in catalogues	Number of native tree species offered in catalogues	Total number of non-native tree species in the country	Total number of native tree species in the country
Urban parks (n = 45)	Trees exhibited in urban parks are selected mostly based on their aesthetics	Number of non-native tree species present in inventories	Number of native tree species present in inventories	Total number of non-native tree species in the country	Total number of native tree species in the country
Inspiration					
Nature photographs (n = 12)	Artistic photographs reflect the choice of inspiring motifs from nature	Number of photographs dominated by non-native trees	Number of photographs dominated by native trees	Cover of non-native trees in the region	Cover of native trees in the region
Cultural heritage					
Monumental trees (n = 21)	Monumental trees are symbols of human culture, sense of place, and history	Number of non-native tree species present in the list	Number of native tree species present in the list	Cover of non-native trees in the region	Cover of native trees in the region

2. Material and methods

2.1. Data collection

2.1.1. Non-native and native tree species

We compiled information on the occurrence and abundance (represented as cover area) of non-native and native tree species in NUTS-2 administrative regions (Eurostat 2015a) of the Iberian Peninsula (southwest Europe). We focused on Continental Portugal (15% of Iberian land area) and Spain, including the Balearic Islands (85% of land area). We considered the whole naturalisation-invasion continuum of tree species in both countries (including planted, naturalised and invasive species; Richardson and Pyšek 2006). Archeophytes and hybrids between non-native and native species were not considered. The lists of non-native trees were obtained from Almeida and Freitas (2006) for Portugal, and from Sanz Elorza et al. (2004) for Spain. The lists of native species were obtained from ICNF (2013a) for Portugal, and from Cela et al. (2013) for Spain.

In total, we considered 157 non-native and 53 native tree species for Portugal; and 261 non-native and 63 native tree species for Spain. Species nomenclature followed Castroviejo et al. (1986-2010); Castroviejo et al., 1986, and was updated following The Plant List (2013). For Portugal, the area covered by non-native and native trees was obtained from the National Land Cover Map – COS 2007 (DGT 2017), and complemented with information from the sixth National Forest Inventory (ICNF, 2013b). For Spain, the cover area was obtained from the third National Forest Inventory – IFN3 1997–2007 (MAPAMA, 2014) and complemented with information from Beltrán et al. (2013). Details on the lists of non-native and native tree species, and on cover areas are shown in Appendices A and B, respectively (Supplementary material).

2.1.2. Cultural ecosystem services

Grounded on the *Millennium Ecosystem Assessment* (MEA 2005), we considered four categories of cultural ecosystem services: recreation and ecotourism, aesthetics, inspiration and cultural heritage. Although other typologies for cultural services are available (e.g., *Common International Classification of Ecosystem Services*), we followed the MEA typology to allow comparability of our results with previous research on cultural services (Hernández-Morcillo et al., 2013; Milcu et al., 2013). For each category of cultural services, we focused on distinct data types and sources. These were selected through a participatory approach implemented under the Cost Action FP1403: *Non-native tree species for European forests – experiences, risks and opportunities* (http://nnext.boku.ac.at/). It involved several academics worldwide as well as literature reviews and consultation with external experts. The selection of data types and sources was made "*considering societal expression of appreciation of ecosystems (…) as a proxy for cultural ecosystem services*" (Hernández-Morcillo et al., 2013: p. 436), and relied on their cost- and time-efficiency, availability, and ease of dissemination across countries worldwide.

Our dataset was obtained through the screening of photographic, internet and catalogue information (following e.g. Hernández-Morcillo et al., 2013; Figueroa-Alfaro and Tang 2017; Oteros-Rozas et al., 2017). For recreation and ecotourism, we focused on two data types: tourism information systems and nature routes. For tourism information systems, data sources comprised official websites of regional tourism. For nature routes, data sources included online nature routes from the "wikiloc" application (http://www.wikiloc.com). In each source, we counted the number of photographs dominated by non-native or native trees. We used a minimum threshold of 50% coverage of a tree to be considered as dominant in the photograph. Aesthetics were evaluated from two data types: catalogues of ornamental plants (online and printed catalogues of local plant dealers), and tree inventories of urban parks (available on the web, books, municipality archives, in-situ panels, and personal surveys). In each source, we counted the number of non-native and native trees. Inspiration services were assessed from collective websites on nature photography for which the location of each photograph was provided. We counted the number of photographs in which non-native or native trees were dominant. Finally, for cultural heritage we counted the number of non-native and native trees indicated in the official lists of monumental tree species of Portugal and Spain.

All data were prior to year 2016 and considered as representative of each one of the 21 NUTS-2 regions of the Iberian Peninsula. More information on data types and respective data sources is shown in Table 1, and further details are provided in Appendix C (Supplementary material).

2.1.3. Environmental and socio-economic predictors

Based on previous knowledge and data availability, a first set of 24 predictors was considered to explain the observed variations of effects of non-native tree on cultural services. The predictors expressed regional patterns of land cover and management, socio-economy, human well-being and climate across the Iberian Peninsula. Land cover and management predictors derived from governmental data and cartography (ICNF, 2013b, for Portugal; MAPAMA, 2014, for Spain). Socio-economic predictors were obtained from Eurostat (2015b), with the human influence index being obtained from WCS and CIESIN (2005), and the development index from Hardeman and Hardeman (2014). Human well-being indicators were obtained from the OECD regional well-being indices (OECD, 2013). The mean values of climatic predictors per region were calculated from maps of the "Iberian Climate Atlas" (Ninyerola et al., 2005), using ArcGIS 10.1 (ESRI, 2012).

All continuous predictors were tested for pair-wise correlations using the non-parametric Spearman test. We excluded 12 predictors from subsequent analyses, due to correlation values above 0.60 when tested against the remaining predictors (Quinn and Keough 2002). The final set of considered predictors is shown in Table 2. Details on predictors and their correlations can be found in Appendix D and E, respectively.

Table 2
Final set of predictors used to explain the variation of effects of non-native tree species on cultural ecosystem services across Iberian NUTS-2 regions.

Code	Predictors
Land cover and management (Vilà and Pujadas 2001; Vicente et al., 2016)	
Forests	Proportion of forest areas
Protected areas	Proportion of protected areas
Socio-economy (Vilà and Pujadas 2001; Krumm and Vítková2016)	
Country	The country where the data sources were located (Portugal or Spain)
Tourism	Number of arrivals at tourist accommodation establishments
Development	EU regional human development index (based on life expectancy, mortality, education, income, and employment)
Impact	Global human influence index (based on human settlement, accessibility, landscape transformation, and electric power infrastructures)
Human well-being (OECD 2013; Ghosh and Traverse 2005; Vaz et al., 2017a)	
Life	Life satisfaction, a subjective well-being index of how people evaluate their life (based on citizens' questionnaires)
Jobs	Job availability, a well-being index of material conditions (based on both employment and unemployment% rates)
Housing	Housing, an index of material conditions for well-being (based on the% ratio of the number of rooms per person)
Environment	Environmental quality, an index of human life quality (based on the estimated average exposure to air pollution in $PM2.5$ μg/m^3)
Climate (Gassó et al., 2009; Vicente et al., 2016)	
Temperature	Minimum temperature of the coldest month (°C)
Precipitation	Total annual precipitation (mm)
Radiation	Annual solar radiation (W/m^2)

2.2. Data analyses

2.2.1. An indicator of non-native tree effects on cultural services

We used the term "effect" to refer to a change promoted by non-native trees on cultural ecosystem services (Jeschke et al., 2014). To describe the direction of this change, we used "increase" or "decrease" of a cultural service, respectively when non-native trees were over- or under-represented in a service (compared to native trees; Table 1). By doing so, an increase or decrease of a service by non-native trees, does not mean an improved or degraded state of the service (Pyšek et al., 2012).

To evaluate the effects of non-native trees, we propose an indicator based on the calculation of the odds ratio. The odds ratio is an effect size statistic, often applied in meta-analysis and case-control studies, as a measure of association between an exposure and an outcome, against the frequency of such outcome if expected by chance (Borenstein et al., 2008). In our case, the odds ratio was assumed to express the direction of effects of non-native tree species (i.e., exposure) in each data source of cultural services (i.e., outcome), compared to the effect of native trees (i.e., non-exposure or comparator). The computation of the direction of effects was further achieved considering the frequency of non-native and native trees in a data source against their frequency in the region (i.e., expected by change), as the control situation (Table 3). For computing the indicator, we first organised the information of each data source (Table 1) in contingency tables (Table 3).

For each data source, we then calculated the odds ratio in its logarithmic form (logOR), using the Peto's method, since some sources showed the absence of non-native or native trees (Borenstein et al., 2008; Viechtbauer 2010; Eqs. (1)–(4)).

$$\Psi = \exp(O - E/V) \tag{1}$$

$$O = A \tag{2}$$

$$E = (A+B)/(A+C)/n \tag{3}$$

$$V = (A+B)(C + D)(A + C)(B + D)/n^2(n - 1) \tag{4}$$

In Eqs. (1)–(4), Ψ is the Peto's odds ratio, and V is both weighting factor and variance for the difference between observed (O) and expected (E) values (see Appendix F for details).

2.2.2. Evaluating the effects of non-native trees on cultural services

For each data type of cultural services, the logORs of all data sources were aggregated in a weighted logOR using the DerSimonian-Laird random effects model. We used this model since it accounts for the variation in logOR across all sources of each data type, in addition to sampling error. Weighted logOR values higher or lower than zero respectively express an over- or under-representation of non-native trees in the cultural service, in comparison to native trees, meaning that non-native trees increase or decrease the cultural service. Weighted logOR equal to zero indicate no effect (or change) on the cultural service (see also Section 2.2.1). We further tested whether the values obtained for each weighted logOR were significantly different from zero, through non-parametric permutation tests with 1000 iterations (Viechtbauer 2010).

To test for significant bias in each data type, we calculated the

Table 3
Example of a contingency table used for calculating the indicator of non-native tree effects on cultural services, based on the odds ratio.

	Amount of non-native trees (Exposure)	Amount of native trees (Non-exposure)
Data source of cultural services (Outcome)	*A*	*B*
NUTS-2 region under analysis (Control)	*C*	*D*

Rosenberg fail-safe number (Rothstein et al., 2005). The fail-safe number estimates the number of additional sources that would be needed to change the results of the weighted logOR from significant to non-significant. When the fail-safe number was larger than *5N + 10* (where *N* is the number of data sources), the weighted logOR could be interpreted as a reliable estimate of true effects (Rothstein et al., 2005). Details on the weighted logOR computation and bias analysis are provided in Appendix G.

2.2.3. Testing the observed variation of non-native tree effects against predictors

For each data type of cultural services, we assessed whether the variation of non-native tree effects could be explained by the 12 predictors (see Table 2). The heterogeneity of logOR across all data sources (expressing the variation of non-native tree effects) was tested using the Q statistic under a chi-square distribution, with n–1 degrees of freedom (Borenstein et al., 2008; Viechtbauer 2010). Values for the Q statistic greater than expected by sampling error suggest an underlying structure of effects in the data type (Borenstein et al., 2008).

When the Q statistic showed significant values, we performed a structured meta-analysis (Viechtbauer 2010). Specifically, for the categorical predictor of country, we computed the weighted logOR of each data type (Peto's method under the DerSimonian-Laird random effects model) for Portugal and Spain, individually. For the continuous predictors, we used a weighted least squares regression to test for significant relations between the predictors and the values of logOR across the sources of each data type. When the regression test showed significant values, we assessed the regression slope and its significance. Significant regression values higher or lower than zero, respectively indicate that non-native trees increase or decrease the cultural service, as the predictor values increase (Viechtbauer 2010).

All statistical procedures were implemented in R software (R Core Team 2014), using the package *metafor* (Viechtbauer 2010).

3. Results

3.1. Effects of non-native trees on cultural ecosystem services

We found contrasting results for the weighted logOR across the different data types of cultural services in the Iberian Peninsula (Fig. 1). Weighted logOR values higher than zero were obtained for tourism information systems (recreation and ecotourism) and for monumental trees (cultural heritage). Conversely, values lower than zero were found for nature routes (recreation and ecotourism), catalogues of plant

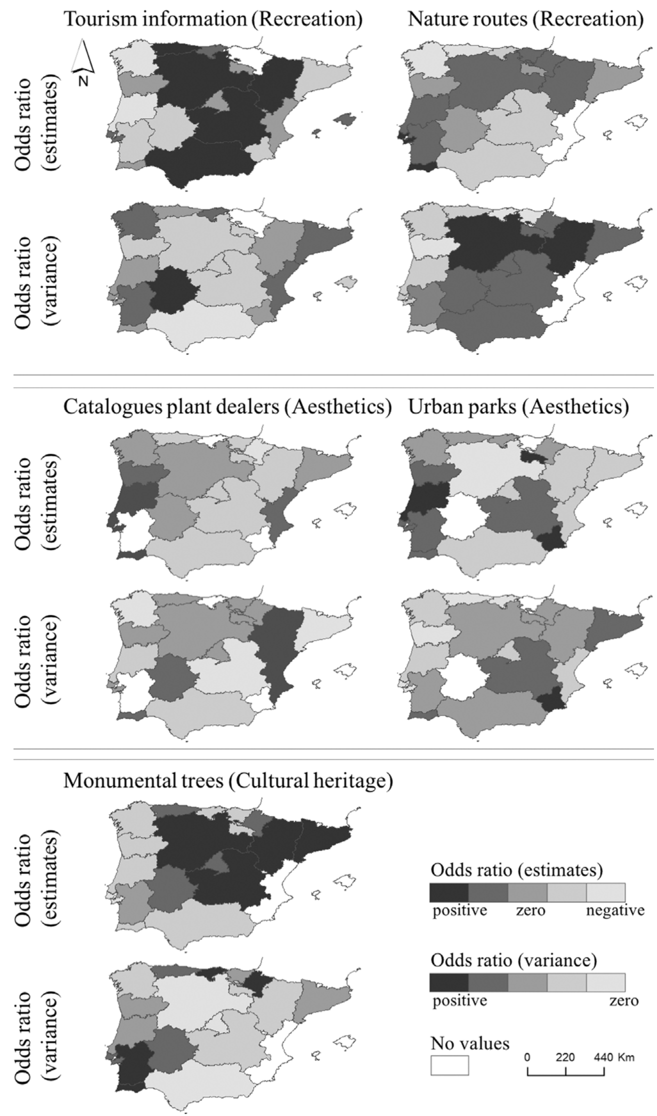

Figure 2. Representation of the spatial distribution of averaged estimates and variance of the log odds ratio for each Iberian NUTS-2 region. Information on nature photographs is not represented since it showed no significant weighted logOR values.

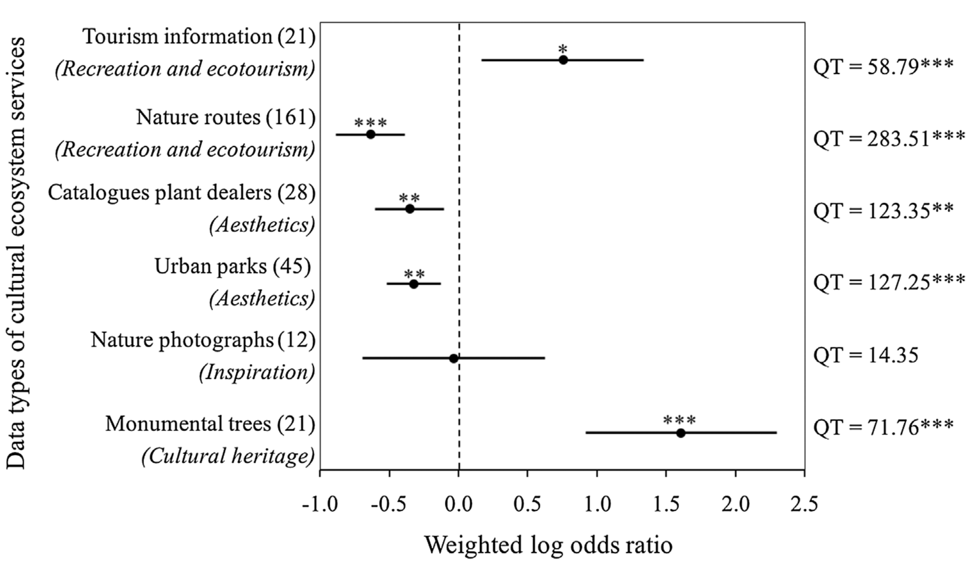

Fig. 1. Weighted log odds ratio (Peto's method under the DerSimonian-Laird random effects model) for each data type of cultural ecosystem services (number of data sources are shown in brackets). Values higher or lower than zero respectively suggest that non-native trees increase or decrease the cultural service, in contrast to native trees. Values on the right indicate the heterogeneity (QT) of the log odds ratio across data sources of each data type, tested by means of the Q statistics. Statistical significance: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 4
Results of the structured meta-analysis assessing the covariation between the considered predictors (Table 2) and the effects of non-native trees (expressed by logORs) on data types of cultural services. The table shows the heterogeneity explained by each predictor and its significance based on a chi-square distribution with n–1 degree of freedom. Values in brackets show the regression slopes and respective significance for continuous predictors (see Appendix H for full results). Statistical significance: *p < 0.05; **p < 0.01; ***p < 0.001.

	Recreation and ecotourism		Aesthetics		Cultural heritage
	Tourism information	*Nature routes*	*Catalogues dealers*	*Urban parks*	*Monumental trees*
Land cover and management					
Forests	0.065	13.567** (−0.037**).	1.358	2.911	0.952
Protected areas	0.101	3.992	0.823	3.168	0.496
Socio-economy					
Country	9.593	52.901***	11.350*	24.152**	23.613
Tourism	2.846	2.199	0.199	11.282** (−0.001***)	0.059
Development	0.024	0.424	4.283* (−1.318*)	0.160	0.323
Impact	0.461	0.640	0.986	1.102	2.978
Human well-being					
Life	1.362	9.389** (−0.590**)	5.961** (−0.511**)	4.721* (−0.384*)	1.774
Jobs	5.063* (−0.285*)	25.257** (−0.268**)	0.366	7.497* (−0.132*)	1.289
Housing	0.024	1.616	0.025	0.001	0.256
Environment	0.000	0.223	0.489	4.737	4.083
Climate					
Temperature	0.288	1.929	4.299* (0.114*)	5.703* (0.114*)	5.301
Precipitation	0.475	5.939* (−0.0001*)	0.745	0.123	0.465
Radiation	0.031	8.178** (0.014**)	0.872	0.506	0.089

dealers (aesthetics) and inventories of urban parks (aesthetics). Fail-safe numbers were higher than *5N + 10* (see Appendix G for full results), meaning that these significant results translate reliable estimates of non-native tree effects. No significant values were obtained for nature photographs (inspiration; Fig. 1).

3.2. Predictors of non-native tree effects on cultural ecosystem services

Significant regional variations of logOR ($p < 0.05$) were observed for most data types, except again for nature photographs (Figs. 1 and 2).

The categorical predictor of country (Portugal or Spain) significantly explained part of logOR variation for catalogues of plant dealers, nature routes and inventories of urban parks. Catalogues of plant dealers resulted on weighted logOR values higher than zero for Portugal (0.47; $p < 0.05$), but lower than zero for Spain (−0.48; $p < 0.01$). Weighted logORs lower than zero were also found for nature routes and urban park inventories, but only for Spain (weighted logOR = −0.95 and −0.48; $p < 0.001$, respectively). No significant values were found for tourism information or for monumental trees (Table 4; see also Appendix G for full results).

Continuous predictors (see Table 2) also contributed to explain the variation of logOR values for most data types, except for monumental trees (Table 4). Job availability was negatively related to logOR values for tourism information, nature routes and urban park inventories. Life satisfaction held a negative relationship with values for nature routes, catalogues of plant dealers, and urban park inventories. Proportion of forests (negative relationship), total annual precipitation (negative) and solar radiation (positive) also explained variation in logOR values for nature routes. Minimum temperature related positively with logOR values for catalogues of plant dealers and urban park inventories. Human development held a negative relationship with values for catalogues of plant dealers, as did tourism rates with values for urban park inventories (Table 4; see also Appendix H for full results).

4. Discussion

4.1. Non-native tree effects on cultural ecosystem services

We developed an indicator-based approach grounded in meta-analytical techniques, and applied it to evaluate the direction of effects of non-native trees on cultural ecosystem services in the Iberian Peninsula. We found that the effects of non-native trees were service-dependent, highlighting the plurality of societal preferences towards cultural ecosystem services (Chan et al., 2012; Ghosh and Traverse 2005; Martín-López et al., 2012). We also found that the effects of non-native trees were country-dependent and determined by some environmental and socio-economic factors. Although holding common geographic and historical features, Portugal and Spain still differ in their climate, demography, politics, culture and economy. These differences could therefore influence the contribution of non-native trees to the multiple cultural services (after Humair et al., 2015; Krumm and Vítková 2016), as previously highlighted for provisioning and regulating services (Brundu and Richardson 2016; Carruthers et al., 2011; Kull et al., 2011).

Specifically, we found contrasting effects from non-native trees on cultural services related to recreation and ecotourism in Iberia. Non-native trees were over-represented (in comparison to native trees) in information systems ruled by official tourism entities, but under-represented in photographs from nature routes experienced by local users, particularly in Spain. In the case of official entities, publicity on Iberian touristic destinations tends to show photographs covering iconic standard features from nature (Santos 2004), which may include non-native species (e.g., palm trees in coastal areas, pines or sequoias in forest areas). Nature route users, however, may enjoy landscapes with more pristine nature features. In both Portugal and Spain, many areas are dominated by non-native trees (e.g., *Eucalyptus globulus*, *Pinus radiata*, *Robinia pseudoacacia*, or *Acacia* species), producing monotonous and homogeneous landscapes that seem to be less attractive to people (following Humair et al., 2015; Kueffer and Kull 2017; Richardson et al., 2014).

We found that non-native trees decreased aesthetic services in the Iberian Peninsula, and particularly in Spain. Still, we found no significant effects of non-natives on the pool of tree species in urban parks in Portugal. This is in contrast to Spain, where legal considerations on the adoption of non-native trees have been explicitly taken for urban areas (Royal Decree-Law 630/2013: 5th disposition). We also found an increase in aesthetic services by non-native trees when focusing on catalogues of plant dealers in Portugal (conversely to Spain), suggesting a market preference for these species. This is of relevance considering that these catalogues include sets of ornamental plants commonly traded in horticulture. Despite legal constraints on the trade of non-native species in both countries (Decree-Laws 565/99 and 630/2013; EU Regulation 1143/2014), horticultural trade is still a main introduction pathway and distribution channel of non-native plants that may become invasive (Hulme et al., 2017; Humair et al., 2015). This is often due to a lack of awareness and information on the non-nativeness of traded ornamental species among sellers, customers, and regulatory entities (Andreu et al., 2009; Carruthers et al., 2011).

We found no significant effects of non-native tree species on inspiration cultural services. This result suggests that the notion of species nativeness in Iberia (i.e., non-natives versus natives) may not influence inspirational preferences of the public and hence photographers, as previously highlighted by Oteros-Rozas et al. (2017) and by van Berkel and Verburg (2014) for rural landscapes. Nevertheless, the non-significance of our result can also express the limited number of observations in our test area. When available, complementary data sources should be explored, namely art museum databases and catalogues, photography literature, and other social media (e.g., Flickr, Panoramio; Figueroa-Alfaro and Tang 2017).

Non-native trees increased cultural heritage services in the Iberian Peninsula, expressed by the over-representation of non-native trees (compared to native trees) in official lists of monumental trees. Monumental trees are part of the cultural heritage at regional and national levels, often representing symbols of human identity for local communities (Asciuto et al., 2015; Crews 2003). In both Portugal and Spain, the monumental status of a tree can be declared due to historical backgrounds, regardless of a native or non-native status (Decree-Law 53/2012: Ordinance 124/2014). The over-representation of non-native trees in this service may express the fact that many non-native trees became monumental trees in Iberia after being introduced as botanical curiosities or research assets during past transatlantic expeditions (e.g., *Camellia japonica* L.), or due to their long-term economic symbolism (e.g., *Eucalyptus globulus*; see also Asciuto et al., 2015; Crews 2003).

4.2. Predictors of non-native tree effects: considerations for management

We found higher increases in recreation and ecotourism, and aesthetic services by non-native trees in NUTS-2 regions with lower socio-economic conditions (tourism rates, development level, job availability) and lower life satisfaction levels. Developed countries are known to host more non-native plant species than developing ones (Humair et al., 2015; Vilà and Pujadas 2001). Our results add that non-native trees seem to be more used (than native trees) for aesthetic and recreational purposes in less developed regions (i.e., under lower income and educational levels). A higher use of non-natives in these regions may be due not only to intrinsic preferences by people, but also to lower awareness on the notion of non-native trees and related risks (following Carruthers et al., 2011; Hulme et al., 2017; Kueffer and Kull 2017). Non-native trees also contributed more to the former services in warmer and drier regions with less forested land. In Iberia, these less developed regions are mostly under warmer and drier climates, and hold fewer forested areas. This may be of importance considering that climate change is expected to increase the likelihood of naturalisation for many ornamental plants, and thus their capacity to alter cultural (and other) ecosystem services (Dullinger et al., 2017; see also Seebens et al., 2015).

The effects of non-native trees on inspiration services and cultural heritage were, however, not explained by the considered predictors. As highlighted by van Berkel and Verburg (2014) and Kueffer and Kull (2017), inspirational and heritage values of non-native trees can also relate to e.g. long-term associations between people and species, human traditions, affections and interests, and symbolic representations of nature, which are difficult to assess outside their regional context. Therefore, our results suggest that the considered social-ecological context may not be of significant relevance for inspirational and heritage services of non-native trees in Iberia, highlighting the need to further explore human psychological and cognitive factors, which were not available for our analyses.

Our results highlight four main ideas to be considered in the management of non-native trees in Iberia. First, the effects of non-native trees on cultural services depend on people's preferences towards visual features. In Iberia, visual attributes of non-native trees are widely associated to homogenised and monotonous landscapes (Kueffer and Kull 2017), explaining the lower consideration of these species for recreation and ecotourism by the general public, but not by official tourism entities. Second, the idea of "out-of-normal" features, as well as of testimonies of historical and cultural events, can be attributed to non-native tree species (Carruthers et al., 2011; Crews 2003). In Portugal and Spain, this can justify the consideration of non-native trees as attractions for recreation and ecotourism by official tourism entities, and as monumental assets in cultural heritage. Third, awareness of the notion of "non-native" associated to tree species depends on the social-ecological context (Kueffer and Kull 2017), and it can influence the ornamental and market value of potentially traded species. Fourth, people from developed socio-economic (including educational) contexts may be more aware of risks associated to non-native species (Vilà and Pujadas 2001; Marchante and Marchante 2016). In Iberia, this can explain why we found a higher contribution of non-native trees to cultural services in less developed regions.

We suggest that management strategies targeting non-native trees should promote awareness, e.g. by means of environmental education programmes, public outreach and further information campaigns (Marchante and Marchante 2016). In Iberia, these campaigns should prioritise tourism entities and ornamental trade, especially in less developed regions. Biosecurity efforts should thus be reinforced among managers, sellers and local residents, who influence interactions among non-native species, social media and market values (Hulme et al., 2017; Humair et al., 2015; Marchante and Marchante 2016). Also, since our research considered non-native trees as a whole, local human perceptions towards individual species should be further considered, as they may differ among species and regions (Kueffer and Kull 2017). Researchers and managers should further examine the motivations underlying the choices and preferences towards non-native ornamental trees (Hulme et al., 2017; Seebens et al., 2015). Promoting risk awareness and strengthening biosecurity efforts, specially focusing on the fact that some of non-natives may naturalize and become invasive (e.g., *Acacia longifolia*, *Pseudotsuga menziesii*, *Robinia pseudoacacia*), could prevent undesirable alterations on ecosystem services (Andreu et al., 2009; Hulme et al., 2017 Vaz et al., 2017a,b).

4.3. Methodological considerations

We proposed an indicator-based approach to obtain preliminary insights on the direction of effects of non-native tree species on cultural services in the Iberia Peninsula. The proposed approach is able to integrate multiple data types from widely available sources of cultural services, allowing reproducibility and the inclusion of further information as data sources expand (Zhang et al., 2016). The approach also has the potential to be applicable to other taxonomic groups, biodiversity measures (e.g. abundance), social-ecological drivers (e.g., pre-and post-invasion processes) and challenges (e.g., ecosystem dis-services), and further temporal and spatial scales (Blicharska et al., 2017; Hernández-Morcillo et al., 2013; Schröter et al., 2016).

Nevertheless, the odds ratio methodology also has some constrains, as it might be sensitive to the choice of data types and control data (represented in our study by the proportion of native and non-native trees in each NUTS-2 region). Despite that our study considered the most relevant and available data to quantify the relations between non-native trees and cultural ecosystem services, we encourage the study of complementary types and sources of information (following e.g., Figueroa-Alfaro and Tang 2017; Oteros-Rozas et al., 2017; van Berkel and Verburg 2014). Particular attention could be given to data types related to inspirational services that did not show significant results in our study. Future studies should also examine information at different time periods and geographic areas, targeting other social-ecological challenges, and consider practical ways to validate results in specific contexts (Hernández-Morcillo et al., 2013; Milcu et al., 2013).

5. Conclusions

We proposed an indicator-based approach to analyse patterns and drivers of cultural ecosystem services. The methodology combines meta-analytical techniques with the collection of different types of information from multiple sources. We applied this approach to the Iberian Peninsula to evaluate the effects of non-native trees on cultural services, i.e., on recreation and ecotourism, aesthetics, inspiration and cultural heritage. Those effects differed among services and countries. In short, non-native trees increased recreation and ecotourism services, when focusing on photographs from official tourism entities, but not from nature route users. Data from inventories of urban parks and catalogues of ornamental plant dealers suggest that non-native trees decreased aesthetics services, particularly in Spain and in contrast to Portugal. We also found an increase of cultural heritage services, expressed by an over-representation of non-native trees (compared to native trees) in catalogues of monumental trees. However, no significant effects were observed on inspiration services. Overall, higher increases of cultural services by non-native trees were observed in less developed regions (i.e., under lower income and educational levels) with lower life satisfaction indices.

Our approach and our results provide pioneer insights into the cultural dimension of non-native trees in Iberia. We recommend that management and biosecurity actions should promote awareness and outreach campaigns on non-native trees. A special focus should be provided to official entities of regional tourism and to ornamental plant dealers, as well as customers and authorities, especially in less developed regions. Finally, we call for studies that expand the proposed approach and explore the role of further global change processes on cultural ecosystem services.

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Appendices A-H. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ecolind.2017.10.009.

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