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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.