Native trees provide more benefits than exotic trees when ecosystem services are weighted in Santiago, Chile

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Abstract

Urban forests are conformed by a variable representation of native and exotic species. Because these species differ in the morpho-functional traits that possess, they may have a differential participation in the provision of ecosystem services in cities. Here, we compare ecosystem services inferred from morpho-functional traits of native and exotic tree species present in Santiago, Chile. Five traits associated with ecosystem services valuation (V_i) were scored (1 versus 0), and compared between native and exotic tree species, weighting those ecosystem services according to multi-criteria decision analysis procedure (MCDA). We found that native and exotic species did not have significant differences in the ecosystem services provided to urban dwellers ($F = 1.2$; $P > 0.05$); but these results were obtained when ecosystem services were not weighted according to their demand in Santiago. When weights were pondered, native species provided more ecosystem services than did exotic trees ($F = 7.1$; $P < 0.008$). Complementarily, we also found that the ecosystem services ranked for native and exotic species did not correlate with their spatial distribution (occupancy, O_i). These results highlight the need to use criteria based on ecosystem services to tree planting in Santiago, prioritizing native species because, in comparison to exotic ones, they provide more ecosystem services demanded city dwellers.

Keywords Alien tree · Ecosystem service · Morpho-functional trait · Tree appraisal · Urban tree

Introduction

Urban areas are undergoing a rapid expansion worldwide that results in complex patterns of landscape configuration and species composition (Millennium Ecosystem Assessment 2005). These transformations demand adjustments of the provision of ecosystem services—i.e., those services associated with human well-being that come from biodiversity (MEA 2005)—toward favoring inhabitants (Güneralp et al. 2013). In this context, for example, it is considered that having an adequate green infrastructure design can help maintain and maximize the ecosystem and socioeconomic services affecting city dwellers (James et al. 2009; Soto et al. 2018), improving life quality and urban sustainability (Tzoulas et al. 2007; Panagopoulos et al. 2016).

Urban trees are important components of the green infrastructure, because they are associated with the provision of diverse ecosystem services (Roy et al. 2012; Gómez-Baggethun and Barton 2013; McBride 2017). These services include mitigation of pollution, microclimatic regulation, water regulation, soil quality, and the production of edible fruits (Nowak and Dwyer, 2007; Fisher et al. 2009;

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Escobedo et al. 2011). As tree species differ in their characteristics and biological attributes (e.g., height, foliage, lifespan, etc.), they participate and contribute differentially in the provision of these ecosystem services (Diaz and Cabido 2001; Roy et al. 2012). Therefore, knowing the environmental needs demanded by a particular city, it may be possible to implement tree planting strategies using tree species that better satisfy these needs (Saebo et al. 2003). Along this line, a key question is which of the ecosystem services demanded by a given city are covered by current urban trees.

Urban forests around the world are composed of a mix of native and exotic species (Alvey 2006; Aronson et al. 2015; Gaertner et al. 2017), with exotic species dominating urban green spaces in some regions, such as South American cities (dos Santos et al. 2010; Santilli et al. 2018; Jaksic and Castro 2020). In this context, a controversy has emerged about the role of native and exotic tree species (Dearnorn and Kark 2010; Conway et al. 2019). On the one hand, some studies promote the use of native trees based mainly on conservation purposes (Sagoff 2005, 2011; Dobbs et al. 2011; Capotorti et al. 2015; Oldfield et al. 2015), while others recommend to take advantage of the ecosystem services provided by tree species, regardless of their biogeographical origin (Sjöman et al. 2016; Potgieter et al. 2017; Riley et al. 2018; Vaz et al. 2018). Therefore, a first step toward making better decisions about native and/or exotic tree species in cities, requires a comparison of ecosystem services provided by these different species (Riley et al. 2018; Conway et al. 2019) to determine if they differentially satisfy the ecosystem services demanded by a particular city (Grote et al. 2016; Conway et al. 2019). Several methods for tree valuation (i.e., appraisal) have been used to determine the specific monetary value of standing trees, attending to tree and forest measurements and health-related variables (e.g., diameter, age, trunk basal area, etc.) and growing conditions (streets, avenues, parks, etc.) in cities (Watson 2002; Grande-Ortiz et al. 2012; Roy et al. 2012; Ponce-Donoso et al. 2017). Nevertheless, these approaches emphasize the economic cost/benefit ratio, paying little attention to ecosystem services provided by these species. Complementarily, an operational and useful approach is based on inferring ecosystem services from the morpho-functional traits of plants (Diaz and Cabido 2001). Indeed, there is growing evidence showing that morpho-functional traits determine ecosystem functioning, including the ecosystem services provided to the well-being of city dwellers (Casanoves et al. 2011; Kattge et al. 2011; Grote et al. 2016; Núñez-Florez et al. 2019).

Santiago is located in the Chilean mediterranean region, also known as central Chile. This region is considered a center of floristic diversity and a biodiversity hotspot of global relevance because it harbors approximately 3500 native plant species, 50% of which are endemic (Myers et al. 2000). Specifically, in central Chile there are 88 native tree

species, 76 (86%) of which are endemic (Rodríguez-Ríos et al. 2006), but these native species are poorly represented within the cities of the region, including Santiago (Escobedo et al. 2006, 2016; Figueroa et al. 2016; Hernández and Villaseñor 2018; Santilli et al. 2018). Indeed, the low representation of native trees in central Chilean cities is striking for some authors (Pauchard and Barbosa 2013; Figueroa et al. 2016; Santilli et al. 2018). Interestingly, the native and exotic tree species in Santiago differ in various morpho-functional traits, which are easily associated with ecosystem services rendered (Hoffmann 1995; Rodríguez-Ríos et al. 2006). For instance, native trees are mainly evergreen species, with sclerophyllous foliage and fleshy fruits, while exotic trees show winter deciduous and broadleaved foliage, and non-fleshy fruits (Hoffmann 1995; Rodríguez-Ríos et al. 2006). Therefore, sustainable planning of the urban forests in Santiago requires identifying morpho-functional traits associated with the ecosystem services provided by native and exotic tree species.

Based on the characterization of five morpho-functional traits of 171 tree species in Santiago, we infer their relative contribution to the provision of ecosystem services. Then, we weight this contribution according to the prioritized requirements for this city (ACHIPPA 2012), seeking an answer to two main questions: (1) Do native and exotic tree species differ in the ecosystem services they provide in Santiago? and (2) Is there a relationship between the representation of trees in Santiago and their contribution to ecosystem services?

Methods

Study city

Santiago is the political-administrative capital of Chile. Currently, it has approximately 6,900,000 inhabitants, an area of 8378 km², and an altitude of about 500 m asl. According to DWUA (2019), Santiago is the seventh most densified city in Latin America (CEPALSTAT 2020), ranking among the 50 most agglomerated cities of the world (DWUA 2019). This city has a temperate mediterranean climate, characterized by cool and rainy winters, and dry and warm summers (Luebert and Pliscoff 2006). Due to the reduced altitude variation (< 200 m) and its location between two mountain ranges, the climatic conditions in Santiago show a reduced spatial variation (see Mcphee et al. 2013).

Species, spatial occupancy and biogeographic origins

An exhaustive tree species list was obtained from floristic sampling (Figueroa et al. 2016; Santilli et al. 2018) and

specialized publications about urban trees in Santiago (Hoffmann 1995; Rodríguez et al. 2006; Alvarado et al. 2013). Thus, a total of 171 species were recognized in Santiago, 21 native and 150 exotics were included in our study. In addition, we obtained the spatial occupancy per species (O_i) from our floristic sampling carried out in Santiago (Figueroa et al. 2016; Santilli et al. 2018). This sampling consisted of the randomized disposition of 200 sites within Santiago, which were visited between 2012 and 2013 (see details in Figueroa et al. 2016). At these sites, we recorded the tree species present in three types of habitats: sidewalks ($n=200$), squares (200) and empty places (200). Then, the spatial occupancy was calculated as the percentage of sampled sites occupied by each species from total set of sampled sites (600 sites); thus, the spatial occupancy was used as a comparative indicator among species of the spatial distribution in Santiago.

The biogeographic origin of each species was extracted from Rodríguez-Ríos et al. (2006) and Santilli et al. (2018). The ‘native’ species were those whose natural distribution correspond to central Chile, while ‘exotic’ species were those that have been introduced from other countries. Because of the small number of native species recorded in Santiago ($n=21$), the six ‘native extralimital’ species (sensu La Sorte and McKinney 2006) were treated as native taxa in Santiago; these species were *A. araucana* (Mol.) Koch, originally distributed in southern Chile (37°–40° S; Rodríguez et al. 2006), outside the geographic range of central Chile (30°36°; Armesto et al. 2007); meanwhile, *Aextoxicon punctatum* Ruiz et Pav., *Schinus areira* L., *Schinus latifolius* (Gillies ex Lindl.) Engl, *Schinus polygamus* (Cav.) Cabrera, and *Sophora cassioides* (Phil.) Sparre show populations in central Chile, whose original range does not include the geographical location of Santiago (Rodríguez et al. 2006).

Ecosystem services and morpho-functional traits

First, we recognized five ecosystem services that trees in Santiago may fulfill; these services were considered among

the most relevant and demanded in the city (see ACHIPPA 2012): (a) mitigation of atmospheric particulate matter during autumn and fall; (b) reduction of irrigation, (c) provision of quality shade during spring and summer; (d) maintenance of nitrified soil; and (e) production of edible fruits. Then, for each 171 tree species we checked for morpho-functional attributes associated with the satisfaction of these services.

Because of the absence of empirical and/or quantitative data for many tree species in Santiago, we used a binary categorization and grossly assigned services to two possible states: high (= 1) and low (= 0) contribution or benefit for urban dwellers. It is important to note that we prefer to use this binary code because it yields standardized comparisons between completely different attributes, thus buffering effects due to the wide variation in scale and taxonomic ranges (Grote et al. 2016; Núñez-Florez et al. 2019). Because three attributes were continuous among species (e.g., hydric requirement; foliage volume and density; nodulation capability; and nitrogen-fixation; see Table 1), the binary code was applied considering the modal value as class-mark for both categories.

These morpho-functional traits and their respective character states were (Table 1): (a) Type of foliage: perennial (1) or deciduous foliage (0), contributing high and low annual retention capacity of atmospheric particulate matter, respectively (Rodríguez-Ríos et al. 2006); (b) Hydric requirement: low (1) or high irrigation requirements (0), related to the water economy; hydric requirements were obtained from ACHIPPA (2012); (c) Foliage architecture: high (1) and low (0) shade quality based on shade production in spring–summer, following to ACHIPPA (2012); (d) Nodulation capability and nitrogen-fixation: good maintenance of organic soils (1) and tree species without this capacity (0), based on the maintenance of soil quality (Tedersoo et al. 2017); (e) Edible fruit: trees producing edible (1) and non-edible fruits (0) that potentially are consumed by urban dwellers (Rodríguez-Ríos et al. 2006).

Table 1 List of morpho-functional traits of urban trees, character stages (assigned scores) and ecosystem services-associated literature sources are given

Morpho-functional traits	Character stage and scores	Sources	Ecosystem service associated in towns
1. Type of foliage	Perennial (1) and caducifolious foliage (0)	Rodríguez et al. (2006)	Mitigation of atmospheric particulate matter, during autumn and fall
2. Hydric requirements	High (0) and low (1) water consumption	ACHIPPA (2012)	Water economy
3. Foliage architecture	A real projection of the foliage shade High (1) and low (0) shade quality	ACHIPPA (2012)	Shade quality and production during spring and summer
4. Nodulation capability and nitrogen-fixation	With nodulation (1) and without nodulation capability (0)	Tedersoo et al. (2017)	Maintenance of soil quality
5. Fruit type	Production of edible fruit to urban dwellers (1) and inedible fruit (0)	Rodríguez-Ríos et al. (2006)	Production of edible fruits

Weighting the ecosystem services (w_i)

The ecosystem services weights (w_i) were determined by the analytic hierarchical process (AHP; Saaty 1980), a multi-criteria decision procedure used to assign priorities among factors contrasted in pairs (Golden et al. 1989). This tool provides a useful approach to cope with the complexity resulting from trade-offs between multiple objectives that cannot be attained at the same time (Belton and Stewart 2002). In addition, this approach allows including a hierarchical valuation upon several criteria mathematically expressed as weights that modulate the importance of some criteria over others (Mustajoki et al. 2020).

The paired comparisons were carried out by consulting five experts about the importance that they assigned to the five ecosystem services under study (Table 2). Basically, experts were individually asked to assign priorities to the paired combination of ecosystem services (Saaty 1980). The expert could assign a value equal to “1” when he/she considered that both services (A and B; Table 2) had equal importance; “3” when service A is slightly more important than B (Table 2); “5” when service A is moderately more important than B (Table 2); “7” when service A is greatly more important than the other (Table 2); and “9” when service A is much more important than B (Table 2). Once the individual judgments of the experts were obtained, the relative weights of each criterion were normalized and calculated in a column vector that indicates the prioritized criteria (see Saaty 1980). Thus, we obtained a hierarchy proportionally weighting each ecosystem service (w_i ; see Table 3) with the greatest demand or need to satisfy. All weights showed a consistency index of 0.95, denoting that the weighting procedure was robust.

Assigning ecosystem valuation (V_i) to tree species and analysis

The relative contributions in ecosystem services that came from different tree species were calculated as:

Table 3 Trait distributions according to native and exotic tree species, associated with character stages in a bivariate scale

Traits	<i>N</i>	Native	Exotic	χ^2	<i>P</i>
Foliage type ($w_1=0.34$)					
Perennial	94	19	75	121	<0.05
Deciduous	77	2	75		
Hydric requirement ($w_2=0.29$)					
Reduced water demand	55	10	45	26	>0.05
High water demand	116	11	105		
Shade quality ($w_3=0.22$)					
Good shade	113	9	104	57	<0.05
Bad shade	58	12	46		
Nodulation capability and nitrogen-fixation ($w_4=0.123$)					
Yes	23	5	18	22	>0.05
No	148	16	132		
Fruit type ($w_5=0.023$)					
Yes	36	2	34	22	>0.05
No	135	19	116		

$$V_i = \sum_{i=1}^n (w_i \cdot C_i),$$

where V_i is the environmental valuation for the i th species, C_i is the score obtained estimated from the i th criterion of environmental valuation, and w_i is the weight of the i th criterion.

We used two analyses to evaluate the V_i between native and exotic species. First, we considered all the ecosystem services as equally important (i.e., $w_i=1$); in a second approach, we used the prioritized valuation according to weight assigned by the experts (Saaty 1980). For both cases, we compared the relative contributions in ecosystem services (V_i) between native and exotic species using a one-way ANOVA test, with the biogeographical origin treated as independent variable, which has two levels (native and exotic origin), while the log-transformed specific environmental valuation (V_i) was included as the dependent variable. We

Table 2 Valuation scale assigned to ecosystem services when these were confronted in pairs

Value	Definition	Explanation
1	Equal importance	Two environmental services are equally demanded (A=B)
3	Weak importance of one over another	Experience and judgment slightly favor one ecosystem service over another (A>B)
5	Essential or strong importance	Experience and judgment strongly favor one ecosystem service over another (A>>B))
7	Demonstrated importance	An ecosystem service is strongly favored and its need is demonstrated over another (A>>>B)
9	Absolute importance	The evidence favoring one ecosystem service over another is of the highest possible order of affirmation (A>>>>B)

This scale was used by five Chilean academic experts that working in environmental disciplines; they had to assign a value between 1 and 9 to describe the importance assigned to one environmental service compared with other (A versus B); even values were considered intermediate between the odd ones (see multi-criteria decision analysis procedure, MCDA; Saaty 1980)

also determined whether V_i was associated with their spatial occupancy (O_i) in the city, using regression analyses between these variables. As it was previously mentioned, the spatial distribution was estimated as the percentage of sites occupied by each tree species from a set of sites provided from previous sampling.

Results

We found that native and exotic tree species did not differ significantly in the ecosystem services provided to urban-dwellers, when these ecosystem services were not weighted according to their demand in Santiago ($F=1.2$; $P>0.05$). Instead, when ecosystem service weights (w_i) were considered, we did find statistical differences for the evaluation of ecosystem services (V_i) provided by either native and exotic species (Fig. 1; $F=7.1$; $P<0.01$). Specifically, native species showed higher levels of ecosystem contribution to citizens than did exotic species in Santiago (Fig. 1). The $V_i (\times 100)$ values for native species ranged between 34 and 97 (Fig. 1a), while V_i values of exotic species were between 0 and 97 (Fig. 1b). Thirteen percent of the exotic species had $V_i<30$, while all native tree species had $V_i>30$ (Fig. 1). The worst evaluated species were *Acer palmatum* Thunb., *Celtis australis* L., *Fagus sylvatica* L., *Ginkgo biloba* L., *Lagerstroemia indica* (L.) Pers., *Magnolia × soulangeana*, and *Syringa vulgaris* L. ($V_i=0$; Supplementary material), all of them exotic species *Acacia*

dealbata Link, *Acacia melanoxylon* R.Br., *Ceratonia siliqua* L., and *Senna candolleana* (Volgel) Irw. and Barn. (all of them, exotic species except for *S. candolleana*) were the best evaluated species ($V_i=97$; Supplementary material).

Valuation differences among trees were due to different weightings and character stages associated with biogeographical origin. Thus, the representation of perennial species was different between native and exotic species ($\chi^2=12.2$; d.f. = 1; $P<0.05$; Table 3), with perennial species being over-represented among native trees (90.4%) while exotic species had an equal proportion of deciduous and perennial trees (50.0%). On the other hand, native and exotic taxa also differed in the fraction of species providing ‘good’ shade quality according to the foliage size and density reached in summer ($\chi^2=5.8$; d.f. = 1; $P<0.05$; Table 3), with 69.3% of exotic species and 42.8% of native species being categorized as good shade quality providers (Table 3). Hydric requirements, nodulation capacities, and edible-fruit production did not show statistical differences when species representation was compared between native and exotic taxa (Table 3).

We did not find a significant positive nor negative relationship between V_i and the occupancy values (O_i) either for native species or exotic trees (Fig. 2). The regression slopes (m) and correlation indices (r^2) did not show statistically difference from zero (Fig. 2), indicating that tree valuation and spatial distribution are currently not associated in Santiago.

Fig. 1 Frequency distributions for ecosystem services valuation ($100 \times V_i$) provided by native (a) and exotic (b) tree species in Santiago, Chile

Fig. 2 Linear regressions between tree valuation (V_i) and species occupancy in Santiago (Chile); open circles correspond to native tree species, and black circles to exotic trees. No significant slopes (m) and correlation indices (r) were found (all of them $P > 0.05$)

Discussion

Although several studies have analyzed the role of urban trees and the ecosystem services they provide to urban-dwellers (Livesley et al. 2016), to our knowledge this is the first article that quantitatively compares the condition of biogeographical origin in trees (i.e., native and exotic). Our findings show that native and exotic tree species do not exhibit statistical differences in the provision of ecosystem services to urban dwellers, but when weights are pondered—according to prioritized demands in Santiago—the native species provide more ecosystem services than do exotic trees. These results provide valuable evidence for the ecosystem role of native trees in Santiago, contrasting with its scarce species richness and abundance (Figueroa et al. 2016; Hernández and Villaseñor 2018), a paradoxical situation that needs to be reverted. The ecosystem services provided by native tree species with evergreen foliage are multiple, temporarily persistent, and highly demanded in Santiago (Escobedo et al. 2011; Guerrero-Leiva et al. 2016).

In previous years, Santiago has been considered one of the most atmospherically polluted cities in South America (MMA 2014), this being the reason why this criterion was valued as the most important among the ecosystem services analyzed ($w_i = 0.34$; Table 1). Tree species can reduce atmospheric pollution by superficial retention and stomatal adsorption in their leaves (Przybysz et al. 2014; Guerrero-Leiva et al. 2016). Atmospheric pollution in Santiago increases during the austral autumn and winter due to meteorological and geographic conditions (Guerrero-Leiva et al. 2016), period during which about 50% of the exotic tree species shed their leaves (Rodríguez-Ríos et al. 2006). In contrast, native tree species have a higher (potential) environmental contribution to pollution mitigation because 90.4% have evergreen foliage, retaining their leaves throughout the most

polluted months (Escobedo et al. 2008; Guerrero-Leiva et al. 2016).

Water economy was valued as the second most important ecosystem service in Santiago (Table 1). This is especially important because cities in central Chile have undergone an extensive drought period (15 years, Garreaud et al. 2019), with climatic predictions indicating that dry conditions will be more frequent and intense in the near and far future (MMA 2014). Currently, Santiago lacks natural forests and all urban forests have been planted (Escobedo et al. 2010, 2016; Figueroa et al. 2016). Thus, trees in the urban forests of Santiago need to be watered for their survival, implying that those species with lower water requirements should be prioritized. Interestingly, according to our qualitative analysis, the native and exotic trees in Santiago do not differ in water requirements, with both groups being dominated by high water-demanding species. However, these results should be taken with caution since they come from indirect or qualitative records (ACHIPPA 2012). On one side, there is a widely shared perception that native trees require less water for their development and maintenance, nevertheless, because native species have evergreen foliage, during the winter season they need water supplement implicating an additional hydric cost that must be empirically measured.

The shade provided by tree species was of better quality among exotic than native species. Indeed, 69.3% of the exotic tree species provide good shade, while only 42.8% of the native species provide good shade. Exotic species have broader and taller foliage providing better shade quality (ACHIPPA 2012; Livesley et al. 2016) while reducing the heat-island effect (Gillner et al. 2015) during the austral summer. Foliage volume and density has been traditionally associated with interception of solar radiation and reduction of the air/soil temperature, both promoting an attenuation of temperatures during the warm season (Livesley et al. 2016). Therefore, the weight given to this criterion

($w_i = 0.22$) should be increased because the aforementioned climate change has produced extremely dry and hot summers (MMA 2017).

Nodulation capability for nitrogen-fixation and production of edible fruits were considered less important traits, but also scarcely represented among native and exotic tree species in Santiago, reaching 12% and 24%, respectively. These services have not been cultural or historically recognized or demanded (Hoffmann 1995; Figueroa et al. 2016; Santilli et al. 2018), and only recently have they reached some importance in Santiago (ACHIPPA 2012). On the other hand, of particular interest is the edible fruit production, because the observed pattern in Santiago contrasts with that of other tropical and South American cities (see Alvarez et al. 2015), where fruits of trees are profusely consumed by urban dwellers (Méndez 2005; Córdova-Stroobandt 2013; Moro and Castro 2015). Indeed, fleshy fruits produced by urban forests in Santiago are scarcely used for consumption, rather they are considered as ornamentals (Hoffmann 1995). The most common exotic tree species with edible fruits in Santiago are *Prunus* spp., *Citrus* spp., and *Malus* spp., while the native maqui [*Aristotelia chilensis* (Mol.) Stuntz] is the most common native species. However, an important constrain for consumption of urban fruits in Santiago city is the potential contamination with particulate matter deposited in the fruit surface, or metals and other toxic compounds absorbed from the soil (Khashroom et al. 2019). In Santiago, there are no studies that have studied this phenomenon.

The lack of relationship between the ecosystem services provided by tree species (V_i) and their spatial occupation (O_i) is a paradoxical finding, and this pattern is applicable to both native and exotic tree species. The absence of an association between ecosystem services and spatial occupation is expected when urban afforestation rests on non-environmental criteria (Millennium Environmental Assessment 2005; Nowak and Dwyer 2007; Fisher et al. 2009; Escobedo et al. 2011; Grote et al. 2016). Currently, the Chilean legal framework (MININT 2004) establishes that municipalities are the entities responsible for selecting, planting, and maintaining public green spaces and infrastructure, but financial resources for these proposals are scarce. Most of the 32 municipalities in Santiago have tree assessment programs based on economic criteria, while others implement their afforestation plans based simply on the tree species available in nurseries (Ponce-Donoso et al. 2017).

At the global scale, the representation of native and exotic species in urban ecosystems constitutes a phenomenon of increasing attention (Alvey 2006; Aronson et al. 2014; McBride 2017). Particularly in south America, several floristic studies in cities show that richness (and abundance) of exotic species—including tree species—exceeds to native ones (Méndez-Stroobandt 2005; Córdova-Stroobandt 2013;

Gartner et al. 2015; Moro and Castro 2015; Figueroa et al. 2016; Santilli et al. 2018); these studies also reveal that the richness of exotic species (approx. 60%) exceeds those recorded from North American, Asian, and European cities (50% as average; see Aronson et al. 2014). As McBride (2017) suggested, this trend is due historical and ornamental criteria implemented in South America post-European colonization (McBride 2017), at the detriment of other considerations (Santilli et al. 2018), such as the provision of ecosystem services.

The question of which tree species are more appropriate for Santiago (i.e., native or exotic), should consider that natives overcome exotic species when prioritization of ecosystem services is included in the analysis. However, it is also important to recognize that this difference is not absolute because several exotic tree species in Santiago are as beneficial as native ones (see Fig. 1). In addition, selection of tree species for urban tree-planting should not only consider the city as a whole but rather focus at smaller spatial scales, such as streets, sidewalks, parks, squares, neighborhoods, etc. (McBride 2017). Indeed, the spatial scale at which afforestation are carried out constitutes a relevant condition for optimizing the environmental services provided by trees; thus, the ecosystem services provided by these plants could be better territorially exploited (Sjöman et al. 2016; Potgieter et al. 2017; Riley 2018; Vaz 2018). Nevertheless, there are at least three reasons for prioritizing native species in Santiago as a whole or in local scales. First, to increase the abundance and richness of the native tree species, which contributes to the provision of ecosystem services demanded by citizens and simultaneously, responding to urgent conservation needs (Cowling et al. 1996; Armesto et al. 2007; Dobbs et al. 2011; Figueroa et al. 2016; Santilli et al. 2018). Certainly, the growth of cities in central Chile has promoted the transformation of the natural landscape, exercising a negative impact on the abundance and distribution of native tree species (Cowling et al. 1996; Armesto et al. 2007). In fact, by far the most part of the native trees currently present in the public areas and private properties of the city have been intentionally planted (de la Maza et al. 2002; Escobedo et al. 2016; Figueroa et al. 2016; Santilli et al. 2018). For this reason, some of these urban spaces could be used for ex situ conservation for native species (Miller and Hobbs 2002). Second, planting native trees improves the ecological integration between Santiago and the peri-urban landscape; this especially responds to future climatic scenarios of dry and hot conditions during summer (McCarthy et al. 2010; Ellison et al. 2017) and high atmospheric pollution events during winter (MMA 2017). This is closely related to the need to mitigate atmospheric pollution between autumn and winter, when this ecosystem service is the most demanded (Préndez 2011; Guerrero et al. 2016). Finally, tree selection for urban forests demands an evaluation of environmental

“disservice” (Nowak and Dwyer 2007; Lyytimäki et al. 2008; Lyytimäki and Sipilä 2009; Dobbs et al. 2011), not included in the present study. In Santiago, two types of environmental tree disservices have been recognized as important: the emission of allergen pollen (Mardones et al. 2011; Criollo et al. 2016) and that of volatile organic compounds (VOC) (Préndez et al. 2013; Egas et al. 2018). Although evidence is scarce for most of the tree species in Santiago city, studies have recognized exotic tree species as more disadvantageous than native trees. Indeed, pollen of exotic trees is known to be highly allergenic to Santiago’s inhabitants (e.g., *Platanus* spp., *Populus* spp.) and VOC emissions (e.g., *Acacia dealbata*, *Betula pendula* Roth, *Melia azedarach* L., *Olea europaea* L., *Prunus* spp., *Robinia pseudoacacia* L.) (Préndez et al. 2013, 2014; Criollo et al. 2016; Egas et al. 2018).

In conclusion, when native and exotic tree species are compared considering the environmental needs for Santiago, the ecosystem services provided by native tree species overcome those provided by exotic ones. Additionally, the spatial representation (i.e., occupancy) of the tree species in Santiago does not exhibit relationship with ecosystem services that they may potentially provide. Thus, we suggest emphasizing the contribution of ecosystem services as criteria to select tree species in Santiago, prioritizing the planting of native species.

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