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Invasion risks and social interest of non-native woody plants in urban parks of mainland Spain

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Abstract. Urban parks and gardens are one of the most important pathways for the deliberate introduction of non-native plant species, some of which cause environmental and socioeconomic impacts. We conducted a risk assessment on 388 non-native woody plant species from 46 urban parks of mainland Spain to classify them in lists based on their invasion status, being invasive elsewhere, climate matching with the area of origin, and potential to cause negative impacts. Only *Ficus benjamina* has no potential to invade (Green list). Four species are invasive and regulated (Priority list); 47 invasive or potentially invasive species can cause more impact types than the median value (Attention list), while 12 can cause less impacts than the median (Watch list). There is no park without any invasive or potentially invasive species. The most common potential impacts could be competition with native species (80% species) and the physical modification of the habitats (71%). We also identified 31 species with potential to cause human health impacts. Some species could cause several impact types. The most correlated potential impacts are among competition, toxicity, and alteration of natural succession and habitat structure. The most frequently planted invasive and potentially invasive species are the ones with the largest standard trending value from Google Trends, and therefore the ones with more societal interest.

Keywords: Google trends, impact assessment, invasive species, ornamental plants, WRA.

Resumen. Los parques y jardines urbanos son una de las vías más importantes de la introducción deliberada de especies de plantas no nativas, algunas de las cuales causan impactos ambientales y socioeconómicos. Realizamos un análisis de riesgo de 388 especies de plantas leñosas no nativas de 46 parques urbanos de España peninsular para clasificarlas en listas basadas en su categoría de invasión en España, la capacidad de ser invasora en otros lugares, la coincidencia climática en su área de origen y el potencial de causar impactos negativos. Solo *Ficus benjamina* no posee potencial invasor (Lista verde). Cuatro especies son invasoras y están reguladas (Lista de prioridad); 47 especies invasoras o potencialmente invasoras pueden causar más impactos que la mediana (Lista de atención), mientras que 12 especies pueden causar menos impactos que la mediana (Lista de observación). No hay parques sin especies invasoras o potencialmente invasoras. Los impactos potenciales más comunes podrían ser la competencia con especies nativas (80%) y la modificación física de los hábitats (71%). Además, identificamos 31 especies con potencial de causar impactos en la salud humana. Algunas especies pueden causar varios tipos de impacto. Los impactos potenciales más correlacionados serían entre competencia, toxicidad, alteración de la sucesión natural y estructura del hábitat. Las especies que se plantan con más frecuencia son las que tienen el mayor valor de tendencia estándar de Google Trends, y por tanto las que poseen un mayor interés social.

Palabras clave: especies invasoras, evaluación de impacto, plantas ornamentales, tendencias de Google, WRA.

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INTRODUCTION

Biological invasions by the establishment and spread of introduced non-native species cause many negative environmental and socioeconomic impacts (Blackburn & al. 2019). Because the establishment of non-native species has increased exponentially during the last decades by the amplified connection of infrastructures and global commerce (Seebens & al. 2017), it is of paramount importance to identify those with the potential to become invasive and cause harm. The introduction of non-native species may be accidental or deliberate. Deliberated introductions of ornamental plants in urban parks and gardens is one of the most important introduction pathways of non-native plants around the globe (Mayer & al. 2017; Haeuser & al. 2018). Despite that ornamental plants provide cultural and aesthetic services to people (Bolund & Hunhammar 1999; Kendal & al. 2012; Vaz & al. 2018), many ornamental introduced species have established (i.e., naturalized) in the wild, causing impacts to biodiversity and ecosystems (Hulme 2007).

The most effective way to manage the impacts of non-native species is prevention through early warning techniques, as well as to perform invasion risk assessments (Convention on Biological Diversity 2010). Development of risk assessment protocols has progressed considerably in the last decades proving to be an essential tool to identify and predict potential invasions (Andreu & Vilà 2010; Roy & al. 2014). Most risk assessment protocols consider being invasive elsewhere, having the potential to be established in the wild, climate matching with the area of origin, and potential to cause impacts as the main characteristics to classify a non-native plant species with high potential to invade a region (Weber & Gut 2004; Otfinowski & al. 2007; Roy & al. 2019). Some classic examples such as the Australian weed risk assessment (WRA) (Pheloung & al. 1999) have been widely used to accurately predict potential invaders in many different regions including Spain (Gordon & al. 2008; Andreu & Vilà 2010; Gassó & al. 2010). However, when focusing on the specific case of non-native plant species introduced for aesthetic purposes, it is likely that additional factors, such as the socioeconomic interest or their planting prevalence, might affect their invasion risk.

The Google Trends tool offers good proxies of the societal interest that the people have on particular items. The Google Trends tool has been used to evaluate the level of interest and queries of the population on conservation topics (Żmihorski & al. 2013; Davies & al. 2018; Schuetz & Johnston 2019) and epidemiology (Seo & Shin 2017). Recently, it has been applied to the study of biological invasions. For example, in Japan, the Google search of 31 major invasive species is a good predictor of their spatial distribution (Fukano & Soga 2019). Likewise the Google Trends has been previously used in Spain to rank non-native plants sold in nurseries (Bayón & Vilà 2019). In this paper, we will use Google Trends to rank ornamental woody plants in urban parks.

Impacts of non-native species are of major concern to prioritize their management (Kumschick & al. 2015; Novoa & al. 2020). Moreover, an understanding about how the impacts interact with each other may provide knowledge on the association between impacts on the environment and on socioeconomic activities (Vilà & al. 2010). Similarly, because plants are deliberately introduced into urban parks, it is important to identify which are the most common and frequent impacts they can cause, both at the species level and at the park ('assemblage') level. Therefore, an analysis of the proportion of species with the potential to cause each impact type and the species occurrence in the parks allows for defining the potential non-native impact profile of a particular park. To our knowledge, this analysis has not been conducted despite its paramount importance to guide best practices for avoiding their threat to local biodiversity and causing disservices.

In this paper, we performed a risk analysis to classify 486 non-native woody species planted in 46 major urban parks from 23 cities across mainland Spain in various lists. Furthermore, for all the invasive and potentially invasive species, we answered the following questions: 1) How frequent are these species across parks? 2) Is species occurrence (i.e., number of parks where present) associated with their interest to society, and with the magnitude of their risk to invade? 3) Which are the most common potential impacts of these species? 4) How frequent are the species with potential to cause impacts in urban parks? and, finally, 5) Which impacts might show higher correlations?

MATERIAL AND METHODS

Urban parks dataset

From the database provided by the Spanish Association of Public Parks and Gardens (AEPJP 2010; see Appendix 1), we compiled the complete species list of woody and arboreal-like plant (i.e., trees, shrubs, arboreal cacti and palm trees) present in 46 parks from 23 peninsular Spanish cities. We used the Taxon stand package of R (Cayuela & al. 2019) to select all the accepted scientific names (consulted 22 May 2020), excluding species with invalid names. The species were classified as native or non-native. Archaeophytes (i.e., species introduced before 1500 AD) were not included in the analysis because they are poorly recorded and, for many species, their non-native status is under discussion (Pyšek & al. 2004).

We checked for the invasion status of these non-native species in Spain (Sanz Elorza & al. 2004; BOE 2019; CABI 2020) following Richardson & al. (2000). Based on that, species were classified as: invasive, established, casual, and not present in the wild. We also consulted their regulatory status by the Spanish Catalogue of Non-native Invasive Species (BOE 2019) and the List of Invasive Alien Species of Union Concern (European Commission 2019). These regulations involve the ban of possession, transport and commerce of living beings and their propagules.

Once we had the five groups of species according to its invasion status in Spain, we proceeded to classify the species into 6 lists following Bayón & Vilà (2019) methodology (Fig. 1):

- Priority list: regulated (by Spain or the EU) invasive non-native species present in urban parks.
- Attention list: invasive (not regulated) and potentially invasive species (i.e., climatically suitable and invasive elsewhere) with more potential impacts than the median of all species.
- Watch list: invasive (not regulated) and potentially invasive species with none or fewer potential impacts than the median of all species.
- Green list: non-invasive nor potentially invasive species with no climatic suitability and probably no potential to be invasive in Spain, and safe for socioeconomics and the environment.
- Uncertainty list: non-invasive species with probably no potential to be invasive and that do not meet the requirements to be included in the Green List. It also includes species with known invasion status but with insufficient information on climatic suitability or being invasives elsewhere.
- Data Deficient list: species without enough information about its invasion status, nor climatic suitability, nor invasive elsewhere. Therefore, they cannot be classified in any other list.

Information on being invasive elsewhere was consulted in the CABI datasheets (CABI 2020) and the database of the Invasive Species Specialist Group (2015). The climatic suitability was defined as the tolerance to both, the highest historical absolute minimum temperature in Spain which was 0.2°C in Almería (9 February 1935), and the highest mean minimum temperature in the coldest month in Spain which is 10.8°C in January in Tarifa (mean recorded from data between 1981 to 2010) (AEMET 2019). These tolerances were consulted in the CABI Invasive Species Compendium (CABI 2020).

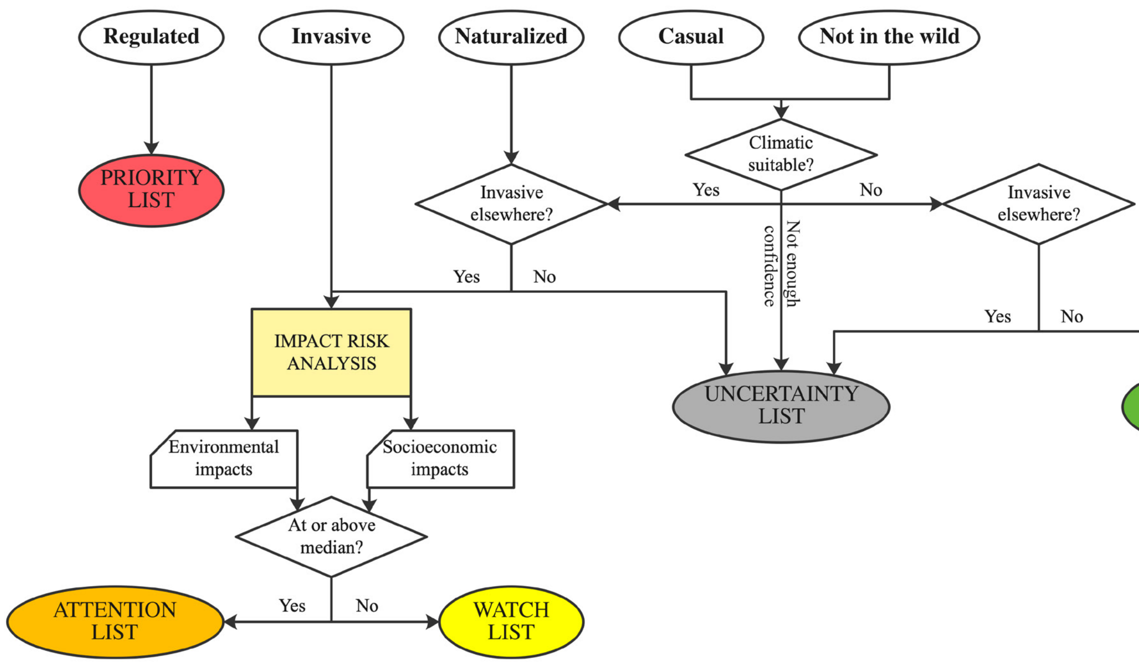

Fig.1. Flow diagram of the risk assessment of ornamental non-native woody species in urban parks and gardens in Spain and their classification into respective lists following Bayón & Vilà (2019).

Impact assessment of invasive and potentially invasive species

For the invasive and potentially invasive species, we assigned binary scores (yes/no) to a total of 14 potential impact types, following Blackburn et al (2014). We considered six potential impacts on native species: (1) competition, (2) hybridization, (3) disease transmission, (4) parasitism, (5) poisoning, toxicity and allelopathy, and (6) interaction with other invasive non-native species; and four impacts on ecosystems: (7) nutrient cycling, (8) physical modification of the habitat, (9) modification of natural succession and (10) disruption to food webs. We also assessed potential socioeconomic impacts, including on (11) human health (such as allergenic pollen), (12) infrastructures, (13) agriculture and forestry and (14) to other sectors (e.g., livestock, domestic animals, and fish farming).

Information on impacts was consulted in the CABI Invasive Species Compendium (CABI 2020) and the database of the Invasive Species Specialist Group (2015). Information about pollen allergenicity was found in the Allergome database (Mari & al. 2009). For each species, we calculated the number of potential environmental (0–10) and socioeconomic (0–4) impacts. The threshold for the classification between species with a high and low number of impacts was the median value for both environmental and socioeconomic impacts. The Attention list was composed by invasive and potentially invasive species in Spain with environmental or socioeconomic impacts at or above the threshold. Meanwhile species with both environmental and socioeconomic impacts below the threshold formed the Watch List.

Society interest analysis of invasive and potentially invasive species

The Google Trends tool provides monthly data of up to five keywords, in a predefined geographic and temporal range. The output values of Google Trends are always relative to the maximum absolute value of all the keywords imputed, which is set as 100. To standardize the relative values of Google trends, we used the R pack "gtrendsR" v. 1.4.2 (Massicotte & Eddelbuettel 2020), carrying out a paired systematic consultation between each species and *Robinia pseudoacacia* L. as the control species for Spain as the geographic region, from the 1st of January of 2004 to the 31st of December of 2019. *Robinia pseudoacacia* was selected as the control species because it was the one with the highest Google Trends value.

Invasion risk assessment of invasive and potentially invasive species

We used an adaptation of the invasion risk assessment (WRA) protocol for Spain (Pheloung & al. 1999; Gassó & al. 2010) on all the invasive and potentially invasive species. The WRA scores range from –14 (benign species) to 29 (maximum risk). WRA assess species as 'rejected' for those species likely to be of high risk (score > 6); as 'accepted' those with a low score (< 1); and as 'need further evaluation', those with intermediate scores (1–6). Some of the WRA values were obtained from several previous studies (Gassó & al. 2010; Pino & al. 2015; Álvarez & al. 2016; Bayón & Vilà 2019). For the species for which WRA had not been performed before, it was calculated 'de novo'. Most of the scientific information to calculate the WRA came from the Invasive Species Specialist Group (2015) and CABI (2020).

Priority Index of invasive and potentially invasive species

For each species in the Attention list, we calculated a Priority Index (PI_i) based on Bayón & Vilà (2019) according to the following equation:

$$PI_i = \frac{\left(\frac{100 \times E_i}{11} + \frac{100 \times S_i}{4} + \frac{100 \times WRA_i}{29} + STV_i\right)}{4}$$

Where: PI_i = Priority Index for species *i*; E_i = number of environmental impacts for species *i*; S_i = number of socioeconomic impacts for species *i*; WRA_i = Weed Risk Assessment score for species *i*; STV_i = Standard trending value for species *i*. The number of potential environmental impacts was set to 11 and not to 10 to be consistent with the Priority Index applied for the first time to nursery species that also included impacts on biofouling (Bayón & Vilà 2019).

Statistical analyses

To test if invasive and potentially invasive species occurrence (i.e., number of parks present) is related to the STV and the WRA, we calculated the Pearson's correlation coefficient, and performed dispersion dot plots by the R ggplot2 package (Wickham 2016); smooth line was performed by 'lm' method.

For the non-native species included in the categories of invasive or potentially invasive species, we seek to describe the occurrence of each potential impact, as well as the associations among impacts and their relative statistical weight.

To answer how frequently species with potential impacts were found in parks, we related how many species were causing each type of impact with their occurrence (mean ± SE) across urban parks. These pairs of values were represented in a scatter plot, including the average values for each variable as reference dash lines.

Data Resources

The complete species database underpinning the analysis, with their potential impacts, reported in this paper, are deposited in the Zenodo repository at https://doi.org/10.5281/zenodo.4295845 (Bayón & al. 2020).

RESULTS

Non-native species lists

From the 486 plants of the database, eight were not at the species level, or had not valid names. Of the remaining, there were 84 native species, 6 archaeophytes and 388 non-native species. From the non-native species, 16 were invasive; four are regulated by the Spanish catalogue (BOE 2019), conforming the Priority List: *Acacia dealbata* Link, present in four parks (8.7%); *Buddleja davidii* Franch., present in two parks (4.3%); *Opuntia ficus-indica* (L.) Mill., present in two parks (4.3%); and *Ailanthus altissima* (Mill.) Swingle, present in 20 parks (43.5%). This last species is also regulated by the European list (European Commission 2019).

Only one species, *Ficus benjamina* L., was classified in the Green list. From the rest of species, 39 were established, 72 were casual, and 33 were not found in the wild. We found information of potential impacts for only 59 invasive and potentially invasive species.

The median number for environmental impacts was four and the median for socioeconomic impacts was one. Forty-seven species (12.1% of total non-native and 79.7% of the invasive and potentially invasive species) had potential impacts at or above these threshold number of potential impacts, conforming the Attention list (Table 1) and 12 species (3.1% of the total non-native and 20.3% of the invasive and potentially invasive species) did not reach the threshold of impacts, and thus conformed the Watch list (Table 2).

Finally, the Uncertainty list (Appendix 2) has 96 species (24.7% of total non-native species). Unfortunately, we could not find information on the 228 remaining species (58.8%), and thus, they were classified in the Data Deficient list (Appendix 3).

Invasive and potentially invasive species occurrence

There are 21 parks (46%) with some regulated species. On average, parks have 0.57±0.11 (mean±SE) invasive regulated species from the Priority List; more concretely, two parks have three regulated species, one park has two regulated species, and 18 parks (39%) have one regulated species. In addition, parks have 8.65±0.97 invasive or potentially invasive species (i.e., species listed in the Attention and Watch Lists) from which 3.15±0.39 are casual, 1.98±0.24 are established, and 2.09±0.27 non-regulated invasive in Spain. A very relevant finding is that we did not find a park without any invasive or potentially invasive species.

There is a significant positive correlation between the occurrence of these 59 invasive and potentially invasive species with the Standard Trending Value (Pearson's R=0.52; p-value<0.001). However, the correlation between species occurrence and their WRA score was not significant (Pearson's R=-0.23; p-value=0.085) (Fig. 2).

Potential impacts of invasive and potentially invasive species

Almost the 80% of the 59 invasive and potentially invasive species have the potential to compete with native species. At the ecosystem level, the most relevant potential impact is the physical modification of the habitat (71% species), followed by impacts on natural succession (56%). The most common potential socioeconomic impact is on human health, with 53% species. The least represented potential impacts are disruption of the food webs (15%), impacts on infrastructures (15%), parasitism (10%) and hybridization with native species (10%) (Fig. 3).

On average, 19.21 ± 3.59 species can cause impacts, and species with potential to cause impact are present in 6.02±1.59 parks. By relating the number of species causing each impact type with their occurrence, according to their average values, we found the following patterns. First, there are three impacts (i.e., human health, physical modification of habitats and competition) that are caused by more species than average. The most frequent impact is on human health, with species causing this impact present in 7.29±1.26 parks. Second, there is one impact (i.e., natural succession) caused by more species than average (33), but they are present in less parks than average (5.58±0.94). Third, there are five impacts (i.e., disease transmission, interaction with other invasive species, and disruption of food webs, on nutrient cycling and on agriculture) that are also caused by less species than average, but they are present in more parks than average. Finally, five impacts (i.e., hybridization, parasitism, poisoning, toxicity and allelopathy, impacts on infrastructures and other socioeconomic impacts) are caused by less species than average and are present in less parks than average (Fig. 4).

There was no negative correlation between any pair of impacts but 18 with significant positive correlations (Fig. 5). The highest correlation was between poisoning, allelopathy and toxicity and impacts on agriculture (Pearson's R=0.52); toxicity is also highly related to human health (R=0.30) and other socio-economic impacts (R=0.37). There were also high correlations, between competition, the different types of toxicity, the alteration of natural succession and the modification of the structure of the habitat, with Pearson's coefficients between R=0.34 and R=0.42. In general terms, there were positive correlations not only between impacts within the same category (i.e., on native species, on ecosystems, and on socioeconomics), but also among impacts across categories.

DISCUSSION

Species lists

The introduction of plants for ornamental purposes is the main deliberate pathway for plant invasions (van Kleunen & al. 2018). Unfortunately, this path includes some of the most harmful invasive plant species (Hulme 2007). In Spain, no park is free of planted invasive or potentially invasive species. One striking result is that almost half of the parks studied have at least one regulated invasive species (Priority List). In the parks analyzed, there are four invasive species (*Ailanthus altissima*, *Acacia dealbata*, *Buddleja davidii* and *Opuntia ficus-indica*) that are regulated and thus their plantation is forbidden (Fifth

Table 1. Attention list: 47 invasive (not regulated) and potentially invasive species with ≥ 4 potential environmental (Env.) impacts or ≥ 1 socioeconomic (Soc.) potential impacts. Status: I = invasive, E = established, C = casual, NW = not in the wild; Climatic confidence suitability: H = high, M = medium; Environmental impacts on Spp. (species); Ecos. (ecosystems); WRA (Weed Risk Assessment): scores < 1 indicate that the species is accepted, scores 1–6 indicate that the species needs further evaluation, scores > 6 indicate that the species is rejected; STV (Standard Trending Value) ranges from 0 to 100; Source: a = Bayón & Vilà 2019, b = Gassó & al. 2010, c = de novo, d = Pino & al. 2015, e = Álvarez & al. 2016, PI (Priority Index). All species are invasive elsewhere except *Schinus molle L.* for which we could not find information.

Species	Family	Status	Climate confidence suitability	Impacts on			No. parks	STV	WRA		PI
				Env.		Soc.			Value	Source	
				Spp.	Ecos.						
Acacia longifolia Paxton	Leguminosae	I	H	1	3	3	1	0	23	a	48
Acer negundo L.	Sapindaceae	I	H	0	1	1	22	52	13	b	33
Berberis thunbergii DC.	Berberidaceae	NW	H	3	1	1	7	41	15	a	39
Broussonetia papyrifera (L.) L'Hér. ex Vent.	Moraceae	E	H	2	3	2	6	41	2	a	36
Brugmansia suaveolens (Willd.) Sweet	Solanaceae	E	M	2	2	2	1	0	13	c	33
Buddleja madagascariensis Lam.	Scrophulariaceae	NW	M	3	2	2	1	0	11	d	33
Casuarina cunninghamiana Miq.	Casuarinaceae	C	H	1	1	2	4	45	15	b	41
Casuarina equisetifolia L.	Casuarinaceae	C	H	2	3	2	8	32	7	a	38
Cestrum nocturnum Lam.	Solanaceae	C	H	2	2	2	4	90	9	a	52
Cinnamomum camphora (L.) J.Presl	Lauraceae	NW	H	3	1	2	2	52	17	a	49
Cornus sericea L.	Cornaceae	NW	H	1	3	1	1	0	22	a	34
Cotoneaster horizontalis Decne.	Rosaceae	NW	H	1	2	1	7	28	26	a	42
Cupressus arizonica Greene	Cupressaceae	C	H	0	0	1	20	53	2	c	21
Elaeagnus angustifolia L.	Elaeagnaceae	I	H	2	4	1	2	28	21	a	45
Elaeagnus pungens Thunb.	Elaeagnaceae	NW	H	1	3	0	4	0	9	c	17
Eriobotrya japonica (Thunb.) Lindl.	Rosaceae	E	H	0	0	1	10	33	7	e	21
Eucalyptus camaldulensis Dehnh.	Myrtaceae	I	H	0	1	1	6	52	17	b	36
Eucalyptus globulus Labill.	Myrtaceae	I	H	3	1	3	4	45	21	a, b	57
Eugenia uniflora L.	Myrtaceae	C	M	3	2	0	1	0	18	a	27
Euonymus fortunei (Turcz.) Hand.-Mazz.	Celastraceae	NW	H	1	3	0	3	0	7	a	15
Ficus rubiginosa Desf. ex Vent.	Moraceae	E	H	3	3	1	1	20	7	a	31
Fraxinus americana L.	Oleaceae	NW	H	0	0	1	1	0	2	c	8
Fraxinus pennsylvanica Marshall	Oleaceae	NW	M	1	0	1	4	0	2	c	10
Gleditsia triacanthos L.	Leguminosae	I	H	2	2	0	10	42	10	a, b	28
Grevillea robusta A.Cunn. ex R.Br.	Proteaceae	C	H	4	3	1	6	53	2	a	37
Lonicera japonica Thunb.	Caprifoliaceae	I	H	1	2	1	6	40	14	a, b	35
Melia azedarach L.	Meliaceae	E	H	2	2	1	10	65	12	a	42
Morus alba L.	Moraceae	C	H	1	2	1	18	78	2	e	34
Nandina domestica Thunb.	Berberidaceae	C	M	3	2	2	7	96	9	a	56
Parkinsonia aculeata L.	Leguminosae	I	H	1	0	2	6	52	15	b	41
Parthenocissus quinquefolia (L.) Planch.	Vitaceae	E	H	2	2	1	6	20	12	c	31
Paulownia tomentosa Lam.	Paulowniaceae	C	H	2	2	1	8	39	19	a	41
Phoenix canariensis Chabaud	Arecaceae	E	H	3	1	2	23	93	6	a	50
Pinus radiata D.Don	Pinaceae	C	H	2	1	2	5	52	12	a	43
Pittosporum undulatum Vent.	Pittosporaceae	E	H	5	4	1	2	0	19	c	43
Rhus typhina L.	Anacardiaceae	E	H	2	3	4	6	0	15	a	49
Ricinus communis L.	Euphorbiaceae	I	H	3	3	3	1	64	20	c	66
Robinia pseudoacacia L.	Leguminosae	I	H	3	4	3	26	100	15	a, b	73
Salix babylonica L.	Salicaceae	C	H	0	2	1	16	52	3	c	26
Schinus molle L.	Anacardiaceae	I	H	0	0	1	4	66	4	b	26
Schinus terebinthifolia Raddi	Anacardiaceae	E	H	4	2	3	2	0	22	c	51
Spiraea japonica L.f.	Rosaceae	C	H	3	1	0	4	40	11	a	29
Tecoma stans (L.) Juss. ex Kunth	Bignoniaceae	C	M	2	2	1	1	0	11	a	25
Thunbergia grandiflora (Roxb. ex Rottl.) Roxb.	Acanthaceae	NW	H	1	1	2	1	0	9	c	25
Wisteria sinensis (Sims) Sweet	Leguminosae	C	H	5	3	2	5	64	9	a	54
Yucca aloifolia L.	Asparagaceae	C	M	2	1	1	6	24	4	a, b	23
Ziziphus jujuba Mill.	Rhamnaceae	E	H	3	2	1	4	23	17	a	38

Table 2. Watch list: 12 invasive (not regulated) and potentially invasive species with < 4 potential environmental (Env.) impacts and no socioeconomic (Soc.) potential impacts in urban parks and gardens in Spain. Status: I = invasive, E = established, C = casual, NW = not in the wild. Climatic confidence suitability : H = high, M = medium; Spp. (species); Ecos. (ecosystems); WRA (Weed Risk Assessment): scores < 1 indicate that the species is accepted, scores 1–6 indicate that the species needs further evaluation, scores > 6 indicate that the species is rejected; STV (Standard Trending Value) ranges from 0 to 100; Source: a = Bayón & Vilà 2019, b = Gassó & al. 2010, c = de novo; PI (Priority Index).

Species	Family	Status	Climatic confidence suitability	Impacts on			No. parks	STV	WRA		PI
				Env.		Soc.			Value	Source	
				Spp.	Ecos.						
Acer platanoides L.	Sapindaceae	E	H	0	3	0	13	52	16	c	31
Albizia julibrissin Durazz.	Leguminosae	E	H	1	1	0	9	53	14	a	32
Berberis aquifolium Pursh	Berberidaceae	NW	H	1	1	0	6	0	-2	c	3
Ficus elastica Roxb. ex Hornem.	Moraceae	NW	H	2	3	0	6	66	6	c	26
Jacaranda mimosifolia D.Don	Bignoniaceae	C	M	1	2	0	10	52	-1	b	17
Lagerstroemia indica L.	Lythraceae	NW	M	2	2	0	15	105	10	c	39
Morus nigra L.	Moraceae	C	H	1	1	0	1	53	4	a	24
Phormium tenax J.R. Forst. & G.Forst.	Xanthorrhoeaceae	I	H	1	3	0	8	53	10	a	29
Pinus patula Schiede ex Schltdl. & Cham.	Pinaceae	NW	M	0	2	0	1	0	0	c	0
Pyrus calleryana Decne.	Rosaceae	NW	H	1	1	0	4	28	1	c	12
Trachycarpus fortunei (Hook.) H.Wendl.	Arecaceae	C	H	1	1	0	21	41	-3	c	10
Zelkova serrata (Thunb.) Makino	Ulmaceae	NW	H	0	2	0	4	0	-4	c	-3

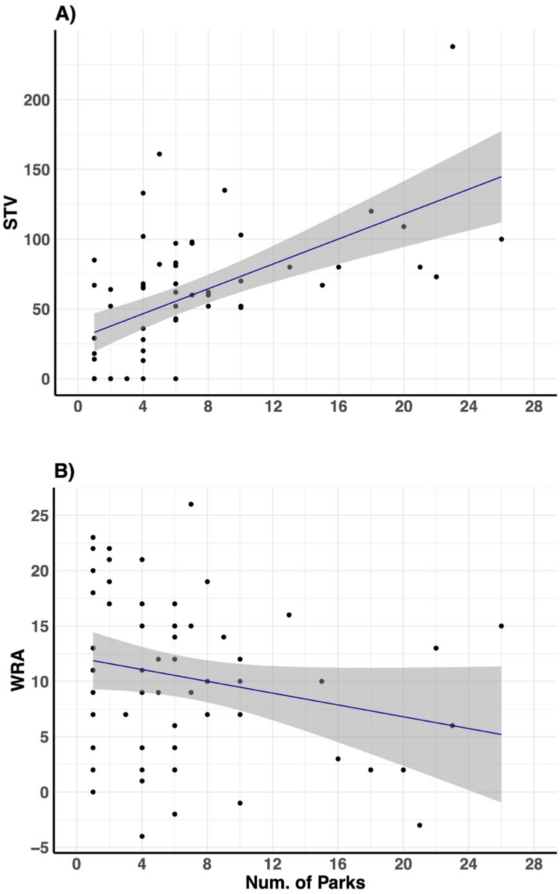

Fig. 2. Correlation between occurrence of invasive and potentially invasive woody species in Spanish urban parks and: A) their Standard Trending Value; (Pearson's R=0.59, p-value<0.001; B) their Weed Risk Assessment score (Pearson's R=-0.22, p-value=0.085). Reference smooth lines performed by 'lm'.

Transitory Provision, BOE 2013). Moreover, *A. altissima*, present in 43.5% of the parks studied, is also listed as invasive by the European Regulation (European Commission 2019). These species shall not be kept, bred or permitted to reproduce or grown, unless it is done in contained holding, where are physically isolated and cannot escape or spread by unauthorized persons (European Commission 2014). Therefore, these species should be removed from the Spanish urban parks.

On the other hand, our analysis identified only one species with no risk to be invasive. *Ficus benjamina* is the only species in our Green list. Based on the consulted scientific evidence (CABI 2020), this species can be planted safely. However, the criteria to classify a species in the Green list is that they are not established in Spain, not invasive anywhere and the climate in mainland Spain is not suitable. The propagule pressure is an important factor determining invasion (Lockwood & al. 2005, 2009), so it is worth considering that planting species in large quantities and in many locations can change this scenario. There are possibly many species in the Data Deficient list that could be moved to the Green list but our methodology is conservative and based on the precautionary principle. We cannot encourage planting non-native species for which there is not enough information on their invasion potential.

One of the highest interests for management are the species belonging to the Attention and the Watch lists. These are invasive and potentially invasive species in which we performed a detailed analysis of the impacts they can cause according to the mechanisms proposed in Blackburn & al. (2014). We recommend that species in the Attention

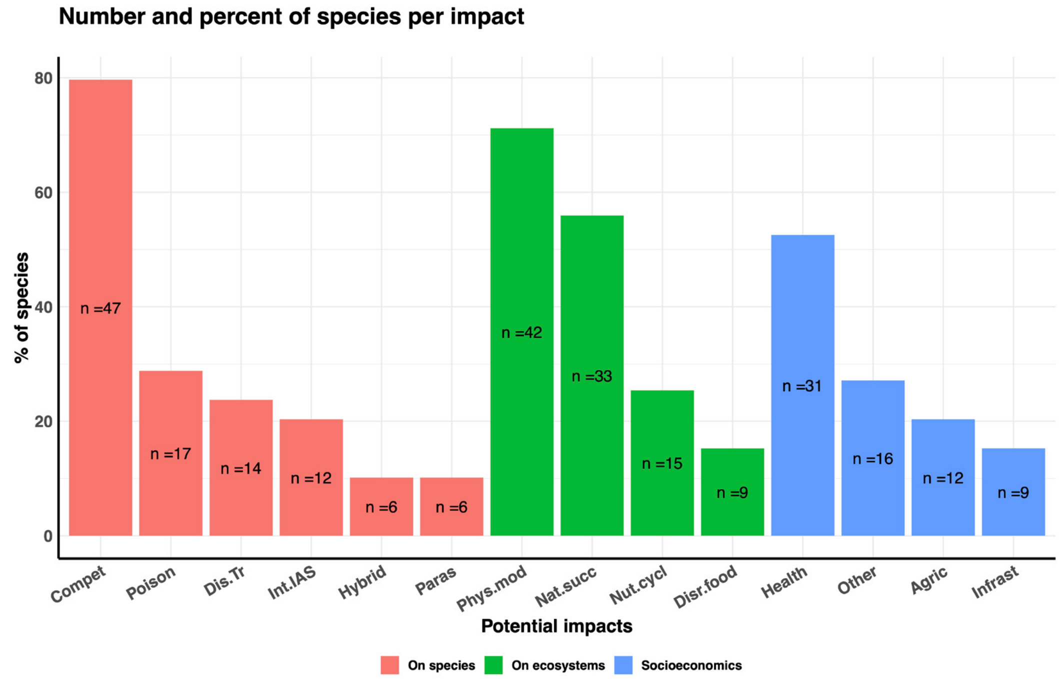

Fig. 3. Potential impacts of 59 invasive and potentially invasive woody species in Spanish urban parks. Impacts are shown from higher to lower percentage of species within each type of impacts: on native species, on ecosystems and on socioeconomic activities. Impacts on species (coral red): Compet = competition; Poison = poisoning, toxicity and allelopathic; Dis.Tr = Disease transmission; Int.IAS = interaction with other invasive non-native species; Hybrid = hybridization with native species; Paras = parasitism. Impacts on ecosystems (green): Phys.mod = physical modification of the habitats; Nat.succ = on natural succession; Nut.cycl = on nutrient cycling; Disr.food = disruption of the food webs. Socioeconomic impacts (blue): Health = on human health including allergenic pollen; Other = other socioeconomic impacts (e.g., livestock, domestic animals, and fish farming); Agric = on agriculture and forestry; Infrast = on infrastructures.

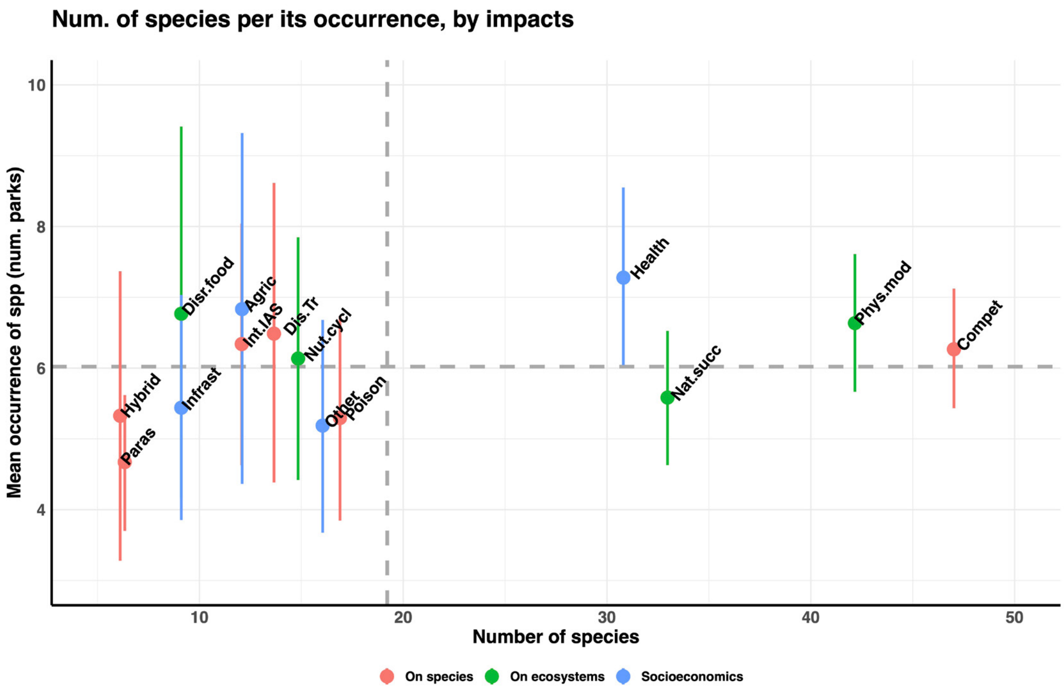

Fig. 4. Number of invasive and potentially invasive woody species per park with the potential to cause each impact type, versus their occurrence (mean ± SE) across parks. Reference dashed lines show the mean value for each axis (x = 19.21 ± 3.59 species with the potential to cause the impact; y = 6.02 ± 1.59 parks in which each species are present). See abbreviations in the caption of Figure 3.

list should be considered for regulation, especially all the species with high Priority Indexes such as *Ricinus communis* L. (PI=73), *Robinia pseudoacacia* (PI=73), *Parkinsonia aculeata* L. (PI=67) and *Eucalyptus globulus* Labill. (PI=65). The remaining species of the Attention list should be at least part of a monitoring program to prevent their spread in natural areas adjacent to parks. Moreover, the 12 species in the Watch list should also be included in early warning and active surveillance programs such as the lists of non-native species potentially capable of competing with native species, altering their genetic purity or ecological balances, set out by the Ministry of Ecological Transition of Spain (BOE 2020).

Because our method is reproducible, new available information has served to provide here some updates compared to a previous risk analysis on nursery plants (Bayón & Vilà 2019). Specifically the species *Cupressus arizonic*a Greene and *Jacaranda mimosifolia* D.Don., that were in the Uncertainty list are now classified in the Watch list because the low number of impacts according to CABI (2020). However, there are still many species (96) in the Uncertainty list and up to 228 species (more than the half non-native species of the whole dataset) in the Data Deficient list, with no data available at all. This is a recurring problem that deserves to be addressed as soon as possible (Bayón & Vilà 2019). We think that periodic updates of species listing are needed, as new information is available (Gallardo & al. 2016), a task that requires a collective effort of a larger team of experts (González-Moreno & al. 2014; Roy & al. 2019).

Society interest on invasive and potentially invasive species

We found a positive correlation between the standard trending values (STV) of the species and their occurrence in the parks. This result reinforces the notion that a greater prevalence of species at urban parks generates greater interest in people. This can cause a fashion-creating effect that can act as a snowball process influencing in turn the interest on some particular species to be planted for instance in private

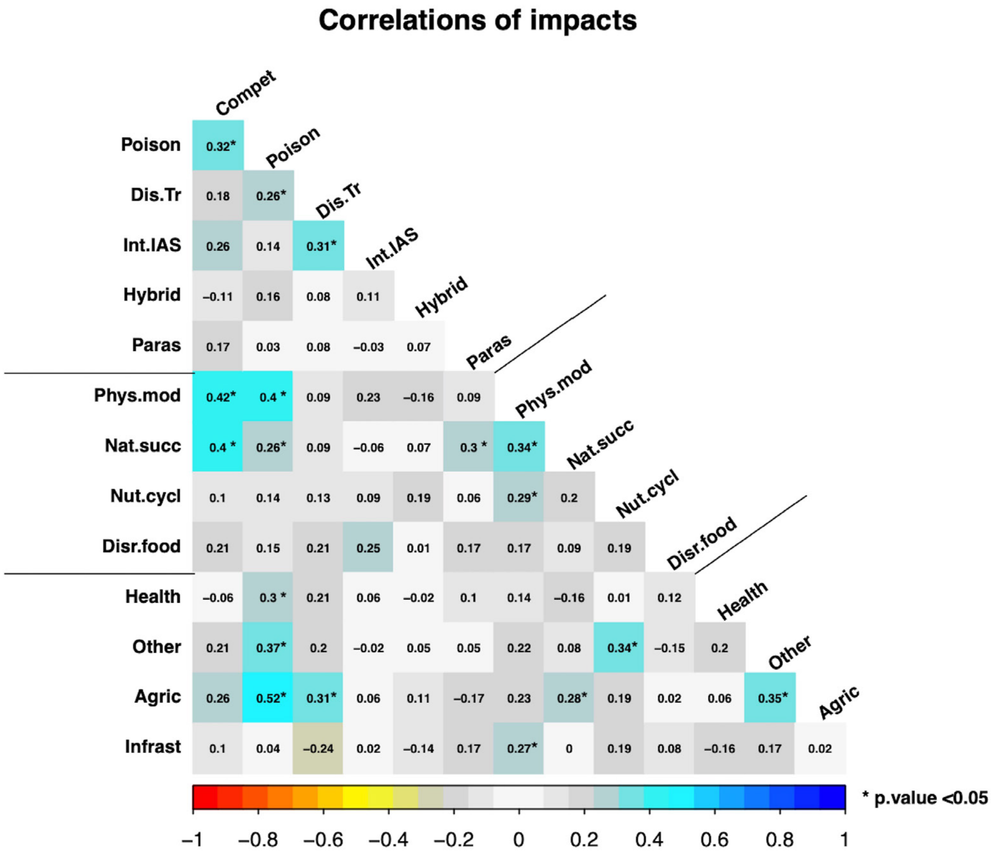

Fig. 5. Correlation matrix (Pearson's R) between potential impacts of invasive and potentially invasive woody species in Spanish urban parks. Impacts on species: Compet = competition; Poison =poisoning, toxicity and allelopathic; Dis.Tr =Disease transmission; Int.IAS =Interaction with other invasive non-native species; Hybrid =hybridization with native species; Paras =parasitism. Impats on ecosystems (green): Phys.mod =Physical modification of the habitats; Nat.succ = on natural succession; Nut.cycl = on nutrient cycling; Disr.food =disruption of the food webs. Socioeconomic impacts (blue): Health = on human health including allergenic pollen; Other =other socioeconomic impacts (e.g., livestock, domestic animals, and fish farming); Agric =on agriculture and forestry; Infrast =on infrastructures.

gardens. It has been proven that an increase in Google, reflected in the Google Trends statistics, is directly related to an increase in private commerce (Vosen & Schmidt 2011). Thus, the presence of invasive and potentially invasive species may be generating an interest, which translates into a greater use of these species, increasing their trade and commerce, and so the dispersion of propagules through the private breeding and cultivation, favoring invasions (Lenda & al. 2014; Hulme & al. 2018). On the other hand, promoting the use of ornamental native species, can generate an awareness effect that favors people's interest on the native flora, and urban parks can also be considered of conservation interest (Alvey 2006; Vaz & al. 2018).

Impacts of invasive and potentially invasive species

The use of non-native species in urban parks is worrisome for the impacts they can cause if they escape and invade natural ecosystems. Eighty percent of the invasive and potentially invasive species can compete with native species, 71% can modify the habitat and 52% can cause human health impacts. The species with the potential to cause these impacts have higher occurrence than average. In particular, there are more than 30 species, which can cause human health problems. Considering that these species cause these impacts due to their traits, (i.e., toxicity, allergenicity, have thorns, etc.) even if they do not establish in the wild, we recommend these species to be removed from parks.

The ability to modify native habitats, to compete with native species, to modify the natural succession, and to be toxic are impacts highly correlated to each other. Our analysis does not demonstrate causality. However, some direct links might take place. For example, allelopathy, included as a toxicity impact, might increase plant competition by influencing soil nutrient availability (Inderjit & del Moral 1997; Medina-Villar & al. 2017); competition with native plants also changes species composition and diversity, and thus, succession and habitat structure (Schoener 1974). Moreover, as this category of impact includes not only allelopathy, but also toxicity and poisoning, they can also cause impacts on human health. In fact, poisoning, allelopathy and toxicity are the impacts with the highest number of correlations, being also highly related to the impacts on agriculture because allelopathy can have an inhibitory effect on crop production (Qasem & Foy 2001), and cause livestock poisoning.

Hybridization and disruption of the food webs are not correlated to any other impact. That the disruption of the food webs is not correlated to other impacts such as competition with native species, the physical modification of the habitats or changes in nutrient cycling is an unexpected result. We think that a deeper analysis of species impact profiles is needed to test whether these unexpected result holds in other species assemblages, or whether our non-significant correlations are due to limited information from the pool of species analyzed. Finally, it is worth mentioning that we did not found cases of counterbalancing impacts, thus synergies are more common than trade-off between pairs of impacts (Vilà & Hulme 2017).

Possible positive effects of introduced non-native species have not been considered in this paper. From a cultural ecosystem service perspective, the presence of non-native trees are highly valued by aesthetics, eco-tourism and as cultural heritage (Vaz & al. 2018) and, although invasive plants are negatively perceived by most people, their management is not perceived as a high priority relative to other environmental risks (Potgieter & al. 2019). Furthermore, non-native trees can also enhance regulating ecosystem services such as climate regulation, soil fertility and erosion control. However in the context of, not only non-native, but also invasive or potentially invasive species, the valuation of impacts in ecosystem services are strongly context dependent varying across tree types, climatic and socioeconomic conditions of the area of introduction (Castro-Díez & al. 2019). For this reason, analyses as the ones described in this paper are of great scientific and management interest.

CONCLUSIONS

We have provided the first risk analysis of the invasion potential of woody species widely planted in representative urban parks across Spain. Overall, our results show that despite invasive and potentially invasive species are a minority of the total number of species present at Spanish urban parks, all parks host some of them. These species have the potential to cause several impacts if they scape and establish in the wild. Interestingly, the ones with the highest interest to society are planted in more parks. Because the introduction of plant species for ornamental purposes is one of the major pathways of invasion (Mayer & al. 2017; Haeuser & al. 2018), our risk analysis indicates that more research is needed on the constraints of ornamental plants to establish in natural areas and to cause impact.

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Appendix 1. List of urban parks consulted for this study.

Name	Aut. Community	City	Year	Area (m^2)	Coord.x	Coord.y
Jardines de la agricultura	Andalusia	Córdoba	1866	30542	37.887663	-4.785697
Jardines del alcázar de los reyes cristianos	Andalusia	Córdoba	1984	31016	37.875082	-4.783087
Parque de la asomadilla	Andalusia	Córdoba	2004	276328	37.904015	-4.776945
Jardines del salón y la bomba	Andalusia	Granada	1831	43891	37.169317	-3.592855
Parque delicias de Arjona	Andalusia	Sevilla	1830	38378	37.371021	-5.989752
Parque María Luisa	Andalusia	Sevilla	1893	265323	37.374600	-5.989055
Jardines de Murillo	Andalusia	Sevilla	1911	28847	37.383335	-5.987854
Parque de Miguel Servet	Aragon	Huesca	1929	65000	42.136854	-0.412700
Parque de la universidad	Aragon	Huesca	2007	31300	42.142034	-0.403913
Parque padre Querbes	Aragon	Huesca	2008	14400	42.141777	-0.419332
Bosque de las olas	Aragon	Huesca	2009	10600	42.129348	-0.409283
Parque mártires de la libertad	Aragon	Huesca	2014	28590	42.144002	-0.402261
Parque del encuentro	Aragon	Huesca	2014	22000	42.141667	-0.400994
Parque cabezo de buena vista	Aragon	Zaragoza	1929	122240	41.631667	-0.893056
Parque grande (J. A. Labordeta)	Aragon	Zaragoza	1929	397000	41.632302	-0.895137
Parque del agua	Aragon	Zaragoza	2008	121000	41.671913	-0.903153
Campo de San Francisco	Asturias	Oviedo	1836	90000	43.361443	-5.850451
Parque doña Casilda Iturrizar	Basque Country	Bilbao	1907	56453	43.265778	-2.941240
Parque de la vaguada de las llamas	Cantabria	Santander	2007	110000	43.473753	-3.802122
Parque de gasset	Castille – La Mancha	Ciudad Real	1915	80674	38.980733	-3.934270
Parque del pilar	Castille – La Mancha	Ciudad Real	1994	78962	38.982841	-3.916800
Parque de San Francisco	Castille and Leon	León	1818	14265	42.593280	-5.571506
Campo Grande	Castille and Leon	Valladolid	1787	115000	41.645678	-4.730281
Parc del laberint d'Horta	Catalonia	Barcelona	1791	91000	41.440204	2.145283
Parc de la ciutadella	Catalonia	Barcelona	1888	170000	41.388171	2.187346
Parc del centre de poblenou	Catalonia	Barcelona	2008	55600	41.407769	2.201317
Jardín de la Vega	Comm. of Madrid	Alcobendas	1994	180000	39.477315	-0.364848
Parque del lago	Comm. of Madrid	Coslada	1927	17050	40.424978	-3.545353
Parque del Jarama	Comm. of Madrid	Coslada	1984	22272	40.442536	-3.531651
Parque del olivo	Comm. of Madrid	Coslada	1990	19075	40.421914	-3.568005
Jardin botánico y museo del bonsai	Comm. of Madrid	Parla	2004	7755	37.980509	-1.130011
Jardines de Méndez Núñez	Galicia	La Coruña	1868	34000	43.367062	-8.403322
Parque botánico del castillo de Soutomaior	Galicia	Pontevedra	1870	30926	42.329449	-8.567276
Parque de a alameda	Galicia	Vigo	1870	12446	42.239340	-8.722475
Parque de la ciudadela y vuelta del castillo	Navarre	Pamplona	1645	280000	42.812040	-1.649290
Parque de la taconera	Navarre	Pamplona	1830	90000	42.811908	-1.613097
Parque fluvial	Navarre	Pamplona	1906	800000	42.821996	-1.611351
Parque de los enamorados	Navarre	Pamplona	1915	32000	42.824663	-1.652507
Parque de la media luna	Navarre	Pamplona	1935	67000	42.814691	-1.633955
Parque del mundo	Navarre	Pamplona	1991	50000	42.832419	-1.626987
Parque yamaguchi	Navarre	Pamplona	1997	82435	42.808743	-1.663111
Las alamedas	Region of Murcia	Lorca	1787	25800	37.672545	-1.694968
Jardín de Floridablanca	Region of Murcia	Murcia	1786	11330	40.536307	-3.631595
Parque de ribalta	Valencian comm.	Castellón de la Plana	1910	78534	39.987671	-0.045085
Jardines del real	Valencian comm.	Valencia	1560	187242	39.480993	-0.367511
Jardín de Monforte	Valencian comm.	Valencia	1859	13583	40.230790	-3.771236

Appendix 2. Uncertainty list. It includes 96 non-invasive and potentially non-invasive species, which lack sufficient information (NA), or those that do not meet the requirements to be included in the Green List. Status: E = established, C = casual, NW = not in the wild. Invasive elsewhere and climate suitability: Y = yes; N = no; Confidence in the likelihood (CL) of climatic suitability: H = high, M = medium, L = low, NA = no available data.

Species	Family	Status	Invasive elsewhere	Climate		No. parks
				Suitability	CL	
Acacia karroo Hayne	Leguminosae	E	NA	NA	NA	1
Aesculus hippocastanum L.	Sapindaceae	E	NA	Y	H	22
Alnus cordata (Loisel.) Duby	Betulaceae	E	NA	Y	H	1
Aloysia citrodora (Hayek) Moldenke	Verbenaceae	C	NA	Y	H	2
Bismarckia nobilis Hildebrandt & H.Wendl.	Arecaceae	NW	NA	N	L	1
Bougainvillea glabra Choisy	Nyctaginaceae	NW	NA	Y	H	4
Brachychiton populneus (Scott & Endl.) R.Br	Malvaceae	C	NA	NA	NA	10
Brahea armata S.Watson	Arecaceae	NW	NA	Y	L	4
Brahea edulis H.Wendl. ex S.Watson	Arecaceae	NW	NA	Y	L	1
Butia capitata (Mart.) Becc.	Arecaceae	NW	NA	Y	L	6
Callistemon citrinus (Curtis) Skeels	Myrtaceae	C	NA	NA	NA	1
Calocedrus decurrens (Torr.) Florin	Cupressaceae	C	NA	NA	NA	9
Carpinus betulus L.	Betulaceae	E	NA	Y	H	13
Catalpa bignonioides Walter	Bignoniaceae	C	NA	NA	NA	16
Cedrus atlantica (Endl.) Manetti ex Carrière	Pinaceae	E	NA	Y	H	24
Cedrus deodara (Roxb. ex D.Don) G.Don	Pinaceae	C	NA	NA	NA	24
Cedrus libani A.Rich	Pinaceae	C	NA	NA	NA	12
Cercis siliquastrum L.	Leguminosae	C	NA	NA	NA	23
Cestrum parqui (Lam.) L'Hér)	Solanaceae	C	NA	NA	NA	1
Chaenomeles speciosa (Sweet) Nakai	Rosaceae	C	NA	NA	NA	3
Chamaecyparis lawsoniana (A.Murray bis) Parl.	Cupressaceae	E	NA	Y	H	12
Citrus sinensis (L.) Osbeck	Rutaceae	C	NA	NA	NA	1
Cordyline australis (G.Forst.) Endl.	Asparagaceae	NW	NA	Y	L	7
Cotinus coggygria (Scop.)	Anacardiaceae	NW	NA	Y	H	2
Cotoneaster lacteus W.W.Sm.	Rosaceae	E	NA	NA	NA	5
Cupressus lusitanica (Mill.) Bartel	Cupressaceae	C	NA	NA	NA	1
Cupressus macrocarpa Hartw.	Cupressaceae	C	NA	NA	NA	13
Cupressus sempervirens L.	Cupressaceae	C	NA	NA	NA	32
Cycas revoluta Thunb.	Cycadaceae	NW	NA	Y	L	8
Cydonia oblonga Mill.	Rosaceae	C	NA	NA	NA	5
Diospyros kaki L.f.	Ebenaceae	C	NA	NA	NA	5
Diospyros lotus L.	Ebenaceae	E	NA	NA	NA	1
Escallonia rubra (Ruiz & Pav.) Pers.	Escalloniaceae	C	NA	NA	NA	6
Eucalyptus gunnii Hook.f.	Myrtaceae	C	NA	NA	NA	2
Euonymus japonicus L.f.	Celastraceae	C	NA	Y	H	18
Hibiscus rosa-sinensis L.	Malvaceae	C	NA	NA	NA	5
Hibiscus syriacus L.	Malvaceae	C	NA	NA	NA	11
Hydrangea macrophylla (Thunb.) Ser.	Hydrangeaceae	E	NA	Y	H	5
Jasminum nudiflorum Lindl.	Oleaceae	C	NA	NA	NA	2
Jasminum officinale L.	Oleaceae	C	NA	Y	H	4
Koelreuteria paniculata Laxm.	Sapindaceae	C	NA	NA	NA	8
Laburnum anagyroides Medik.	Leguminosae	E	NA	Y	H	3
Lagunaria patersonia (Andrews) G.Don	Malvaceae	C	NA	NA	NA	3
Lantana montevidensis (Spreng.) Briq.	Verbenaceae	C	NA	NA	NA	1
Larix decidua Mill.	Pinaceae	C	NA	NA	NA	1
*Ligustrum lucidum*W.T.Aiton	Oleaceae	C	NA	NA	NA	10
Ligustrum ovalifolium Hassk.	Oleaceae	C	NA	NA	NA	5
Ligustrum vulgare L.	Oleaceae	E	NA	Y	H	4

Appendix 2. Contd.

Species	Family	Status	Invasive elsewhere	Climate		No. parks
				Suitability	CL	
Livistona chinensis (Jacq.) R.Br. ex Mart.	Arecaceae	NW	Y	N	L	8
Loropetalum chinense (R.Br.) Oliv.	Hamamelidaceae	NW	NA	Y	M	1
Maclura pomifera (Raf.)	Moraceae	C	NA	NA	NA	2
Malus domestica (Suckow) Borkh.	Rosaceae	C	NA	NA	NA	2
Malvaviscus arboreus Dill. ex Cav.	Malvaceae	NW	Y	Y	L	2
Mespilus germanica L.	Rosaceae	E	NA	Y	H	1
Montanoa bipinnatifida (Kunth) K.Koch	Compositae	E	NA	Y	H	2
Muehlenbeckia complexa (A.Cunn.) Meisn.	Polygonaceae	E	NA	Y	H	1
Myrtus communis L.	Myrtaceae	E	NA	Y	H	11
Parthenocissus tricuspidata (Siebold & Zucc.) Planch.	Vitaceae	E	NA	Y	H	2
Phoenix dactylifera L.	Arecaceae	E	NA	Y	H	13
Photinia serratifolia (Desf.) Kalkman	Rosaceae	C	Y	NA	NA	8
Phytolacca dioica L.	Phytolaccaceae	C	NA	NA	NA	9
Picea abies (L.) H.Karst.	Pinaceae	E	NA	Y	H	10
Picea sitchensis (Bong.) Carrière	Pinaceae	C	NA	NA	NA	1
Pinus canariensis C.Sm. ex DC.	Pinaceae	C	NA	NA	NA	8
Pinus ponderosa Douglas ex C.Lawson	Pinaceae	C	NA	NA	NA	1
Pinus strobus L.	Pinaceae	C	NA	NA	NA	1
Pittosporum tenuifolium Gaertn.	Pittosporaceae	NW	NA	Y	L	2
Pittosporum tobira (Thunb.) W.T.Aiton	Pittosporaceae	C	NA	NA	NA	19
Populus deltoides W.Bartram ex Marshall	Salicaceae	E	NA	NA	NA	2
Populus simonii Carrière	Salicaceae	C	NA	NA	NA	2
Prunus armeniaca L.	Rosaceae	C	NA	NA	NA	2
Prunus cerasifera Ehrh.	Rosaceae	E	NA	Y	H	21
Prunus domestica L.	Rosaceae	C	NA	NA	NA	2
Prunus laurocerasus L.	Rosaceae	E	NA	Y	H	13
Prunus triloba Lindl.	Rosaceae	C	NA	NA	NA	1
Pseudotsuga menziesii (Mirb.) Franco	Pinaceae	C	NA	NA	NA	3
Pyracantha angustifolia (Franch.) C.L.Schneid.	Rosaceae	C	NA	NA	NA	1
Pyracantha coccinea M.Roem.	Rosaceae	NW	Y	Y	L	13
Pyracantha crenatoserrata (Hance) Rehder	Rosaceae	C	NA	NA	NA	1
Pyrus communis L.	Rosaceae	C	NA	NA	NA	3
Quercus cerris L.	Fagaceae	C	NA	NA	NA	2
Quercus rubra L.	Fagaceae	E	NA	Y	H	6
Rumex lunaria L.	Polygonaceae	C	NA	NA	NA	1
Salix viminalis L.	Salicaceae	NW	NA	Y	H	1
Sequoiadendron giganteum (Lindl.) J.Buchholz	Cupressaceae	E	NA	Y	H	10
Serenoa repens (W.Bartram) Small	Arecaceae	NW	NA	Y	L	2
Spiraea cantoniensis Lour.	Rosaceae	C	NA	NA	NA	2
Styphnolobium japonicum (L.) Schott	Leguminosae	NW	NA	Y	H	25
Syringa vulgaris L.	Oleaceae	C	NA	NA	NA	8
Tamarix parviflora DC.	Tamaricaceae	E	NA	Y	H	1
Tipuana tipu (Benth.) Kuntze	Leguminosae	C	NA	NA	NA	5
Ulmus pumila L.	Ulmaceae	C	Y	Y	L	14
Washingtonia filifera (Rafarin) H.Wendl. ex de Bary	Arecaceae	C	NA	NA	NA	16
Washingtonia robusta H.Wendl.	Arecaceae	E	NA	Y	H	9
Wisteria floribunda (Willd.) DC.	Leguminosae	C	NA	NA	NA	2
Yucca gloriosa L.	Asparagaceae	E	NA	Y	H	4

Appendix 3. Data Deficient list. It includes 228 species for which we did not have found sufficient data for analysis.

Species	Family
Abelia triflora R.Br. ex Wall.	Caprifoliaceae
Abies cephalonica Loudon	Pinaceae
Abies concolor (Gordon & Glend.) Lindl. ex Hildebr.	Pinaceae
Abies nordmanniana (Steven) Spach	Pinaceae
Abies procera Rehder	Pinaceae
Abutilon pictum (Gillies ex Hook.) Walp.	Malvaceae
Acca sellowiana (O.Berg) Burret	Myrtaceae
Acer buergerianum Miq.	Sapindaceae
Acer cappadocicum Gled.	Sapindaceae
Acer davidii Franch.	Sapindaceae
Acer palmatum Raf.	Sapindaceae
Acer rubrum L.	Sapindaceae
Acer saccharinum L.	Sapindaceae
Acer tataricum L.	Sapindaceae
Alnus incana (L.) Moench	Betulaceae
Amelanchier ovalis (Willd.) Borkh	Rosaceae
Amomyrtus luma (Molina) D.Legrand & Kausel	Myrtaceae
Araucaria angustifolia (Bertol.) Kuntze	Araucariaceae
Araucaria araucana (Molina) K.Koch	Araucariaceae
Araucaria bidwillii Hook.	Araucariaceae
Araucaria columnaris (G.Forst.) Hook.	Araucariaceae
Araucaria cunninghamii Mudie	Araucariaceae
Araucaria heterophylla (Salisb.) Franco	Araucariaceae
Archontophoenix alexandrae (F.Muell.) H.Wendl. & Drude	Arecaceae
Arenga engleri Becc.	Arecaceae
Atriplex halimus L.	Amaranthaceae
Aucuba japonica Thunb.	Garryaceae
Bauhinia forficata Link	Leguminosae
Bauhinia variegata L.	Leguminosae
Berberis candidula (C.K.Schneid.) C.K.Schneid.	Berberidaceae
Berberis julianae C.K.Schneid.	Berberidaceae
Berberis wilsoniae Hemsl.	Berberidaceae
Betula papyrifera Marshall	Betulaceae
Betula pendula Roth	Betulaceae
Betula utilis D.Don	Betulaceae
Bougainvillea spectabilis Willd.	Nyctaginaceae
Brachychiton acerifolius (A.Cunn. ex G.Don) F.Muell.	Malvaceae
Brachychiton discolor F.Muell.	Malvaceae
Brugmansia arborea (L.) Sweet	Solanaceae
Butia yatay (Mart.) Becc.	Arecaceae
Buxus microphylla Siebold & Zucc.	Buxaceae
Callistemon lanceolatus (Sm.) Sweet	Myrtaceae
Callistemon speciosus (Sims) Sweet	Myrtaceae
Camellia japonica L.	Theaceae
Carissa macrocarpa (Eckl.) A.DC.	Apocynaceae
Carya illinoinensis (Wangenh.) K.Koch	Juglandaceae
Carya laciniosa (F.Michx.) G.Don	Juglandaceae
Caryota urens L.	Arecaceae
Castanea dentata (Marshall) Borkh.	Fagaceae
Catalpa bungei C.A.Mey.	Bignoniaceae
Ceiba speciosa (A.St.-Hil.) Ravenna	Malvaceae
Celtis occidentalis L.	Cannabaceae
Cephalotaxus fortunei Hook.	Taxaceae
Cercis chinensis Bunge	Leguminosae
Cestrum aurantiacum Lindl.	Solanaceae
Cestrum elegans (Brongn. ex Neumann) Schldtl.	Solanaceae
Chaenomeles japonica (Thunb) Lindl. ex Spach	Rosaceae
Chamaecyparis obtusa (Siebold & Zucc.) Endl.	Cupressaceae
Choisya ternata Kunth	Rutaceae
Citrus maxima (Burm.) Merr.	Rutaceae
Citrus medica L.	Rutaceae
Coprosma repens A.Rich	Rubiaceae
Cordyline indivisa (G.Forst.) Endl.	Asparagaceae
Cordyline rubra Otto & A.Dietr.	Asparagaceae
Cornus florida L.	Cornaceae
Corylus colurna L.	Betulaceae
Cotoneaster franchetii Bois	Rosaceae
Cotoneaster pannosus Franch.	Rosaceae
Cotoneaster salicifolius Franch.	Rosaceae
Crataegus crus-galli L.	Rosaceae
Cryptomeria japonica (Thunb. ex L.f.) D.Don	Cupressaceae
Cupressus cashmeriana Royle ex Carrière	Cupressaceae
Cupressus funebris Endl.	Cupressaceae
Cupressus nootkatensis D.Don	Cupressaceae
Cycas circinalis L.	Cycadaceae
Dasylirion acrotrichum (Schiede) Zucc.	Asparagaceae
Deutzia scabra Thunb.	Hydrangeaceae
Diosma hirsuta L.	Rutaceae
Dodonaea viscosa Jacq.	Sapindaceae
Dolichandra unguis-cati (L.) L.G.Lohmann	Bignoniaceae
Dracaena draco (L.) L.	Asparagaceae
Echinocactus grusonii Hildm.	Cactaceae
Erythrina caffra Thunb.	Leguminosae
Erythrina crista-galli L.	Leguminosae
Escallonia paniculata Phil.	Escalloniaceae
Escallonia rosea Griseb.	Escalloniaceae
Eucalyptus cinerea F.Muell. ex Benth.	Myrtaceae
Eucalyptus diversicolor F.Muell.	Myrtaceae
Eucalyptus pauciflora Sieber ex Spreng.	Myrtaceae
Euonymus europaeus L.	Celastraceae
Fatsia japonica (Thunb.) Decne. & Planch.	Araliaceae
Ficus binnendijkii Miq.	Moraceae
Ficus craterostoma Warb. ex Mildbr. & Burret	Moraceae
Ficus drupacea Thunb.	Moraceae
Ficus macrophylla Pers,	Moraceae
Firmiana simplex (L.) W.Wight	Malvaceae
Ginkgo biloba L.	Ginkgoaceae
Gymnosporia heterophylla (Eckl. & Zeyh.) Loes.	Celastraceae
Hamamelis mollis Oliv.	Hamamelidaceae
Harpephyllum caffrum Bernh.	Anacardiaceae
Howea forsteriana (F.Muell.) Becc.	Arecaceae
Ilex cornuta Lindl. & Paxton	Aquifoliaceae
Iochroma cyaneum (Lindl.) M.L.Green	Solanaceae
Jasminum azoricum L.	Oleaceae
Jasminum fruticans L.	Oleaceae
Jasminum grandiflorum L.	Oleaceae
Jasminum humile L.	Oleaceae
Jubaea chilensis (Molina) Baill.	Arecaceae
Juglans nigra L.	Juglandaceae
Juniperus chinensis L.	Cupressaceae
Juniperus horizontalis Moench	Cupressaceae
Juniperus virginiana L.	Cupressaceae
Justicia adhatoda L.	Acanthaceae
Justicia brandegeeana Wassh. & L.B.Sm.	Acanthaceae

Appendix 3. Contd.

Species	Family
Justicia carnea Lindl.	Acanthaceae
Justicia floribunda (C.Koch) Wassh.	Acanthaceae
Kennedia rubicunda Vent.	Leguminosae
Kerria japónica (L.) DC.	Rosaceae
Kolkwitzia amabilis Graebn.	Caprifoliaceae
Ligustrum japonicum Thunb.	Oleaceae
Liquidambar styraciflua L.	Altingiaceae
Liriodendron tulipifera L.	Magnoliaceae
Livistona australis (R.Br.) Mart.	Arecaceae
Livistona decora (W.Bull) Dowe	Arecaceae
Lonicera caprifolium L.	Caprifoliaceae
Lonicera fragrantissima Lindl. & J.Paxton	Caprifoliaceae
Lonicera implexa Aiton	Caprifoliaceae
Lonicera ligustrina Wall.	Caprifoliaceae
Lonicera sempervirens L.	Caprifoliaceae
Magnolia grandiflora L.	Magnoliaceae
Magnolia virginiana L.	Magnoliaceae
Mahonia bealei (Fortune) Pynaert	Berberidaceae
Mahonia japónica (Thunb.) DC.	Berberidaceae
Malus floribunda Siebold ex Van Houtte	Rosaceae
Malvaviscus penduliflorus Moc. & Sessé ex DC.	Malvaceae
Metasequoia glyptostroboides Hu & W.C.Cheng	Cupressaceae
Metrosideros excelsa Sol. ex Gaertn.	Myrtaceae
Morus australis Poir.	Moraceae
Myrsine africana L.	Primulaceae
Nannorrhops ritchieana (Griff.) Aitch.	Arecaceae
Nothofagus menziesii (Hook.f.) Oerst.	Nothofagaceae
Nyssa sylvatica Marshall	Cornaceae
Osmanthus fragrans (Oackley) Archila	Oleaceae
Osmanthus heterophyllus (G.Don) P.S.Green	Oleaceae
Ostrya carpinifolia Scop.	Betulaceae
Ostrya virginiana (Mill.) K.Koch	Betulaceae
Parajubaea cocoides Burret	Arecaceae
Parajubaea torallyi (Mart.) Burret	Arecaceae
Peltophorum dubium (Spreng.) Taub.	Leguminosae
Persea indica (L.) Spreng.	Lauraceae
Philadelphus coronarius L.	Hydrangeaceae
Phoenix reclinata Jacq.	Arecaceae
Phoenix roebelenii O'Brien	Arecaceae
Phoenix sylvestris (L.) Roxb.	Arecaceae
Photinia glabra (Thunb) Maxim.	Rosaceae
Phymosia umbellata (Cav.) Kearney	Malvaceae
Picea glauca (Moench) Voss	Pinaceae
Picea pungens Engelm.	Pinaceae
Pinus nigra J.F.Arnold	Pinaceae
Pinus pumila (Pall.) Regel	Pinaceae
Pinus roxburghii Sarg.	Pinaceae
Pittosporum coriaceum Aiton	Pittosporaceae
Pittosporum crassifolium Banks & Sol. ex A.Cunn.	Pittosporaceae
Pittosporum truncatum E.pritz.	Pittosporaceae
Platanus orientalis L.	Platanaceae
Podocarpus macrophyllus (Thunb.) Sweet	Podocarpaceae
Podocarpus neriifolius D.Don	Podocarpaceae
Podranea ricasoliana (Tanfani) Sprague	Bignoniaceae
Populus yunnanensis Dode	Salicaceae
Prunus fruticosa Pall.	Rosaceae
Prunus maackii Rupr.	Rosaceae
Prunus sargentii Rehder	Rosaceae
Prunus serrulata Lindl.	Rosaceae
Prunus subhirtella Miq.	Rosaceae
Prunus virginiana L.	Rosaceae
Pyrus salicifolia Pall.	Rosaceae
Quercus castaneifolia C.A.Mey.	Fagaceae
Quercus macrocarpa Michx.	Fagaceae
Quercus palustris Münchh.	Fagaceae
Quercus polymorpha Schltdl. & Cham.	Fagaceae
Quercus rysophylla Weath.	Fagaceae
Rhaphiolepis indica (L.) Lindl.	Rosaceae
Rhapis excelsa (Thunb.) Henry	Arecaceae
Rhapis humilis Blume	Arecaceae
Rhododendron indicum (L.) Sweet	Ericaceae
Rhus copallinum L.	Anacardiaceae
Ribes sanguineum Pursh	Grossulariaceae
Roldana petasitis (Sims) H.Rob. & Brettell	Compositae
Ruscus aculeatus L.	Asparagaceae
Ruscus hypophyllum L.	Asparagaceae
Sabal bermudana L.H.Bailey	Arecaceae
Sabal mexicana Mart.	Arecaceae
Sabal minor (Jacq.) Pers.	Arecaceae
Sabal palmetto (Walter) Lodd. ex Schult. & Schult.f	Arecaceae
Salix daphnoides Vill.	Salicaceae
Salix humboldtiana Willd.	Salicaceae
Salix nigra Marshall	Salicaceae
Sambucus ebulus L.	Adoxaceae
Sequoia sempervirens (D.Don) Endl.	Cupressaceae
Skimmia japónica Thunb.	Rutaceae
Sorbus intermedia (Ehrh.) Pers.	Rosaceae
Sorbus torminalis (L.) Crantz	Rosaceae
Sparrmannia africana L.f.	Malvaceae
Spiraea crenata L.	Rosaceae
Spiraea hypericifolia L.	Rosaceae
Syagrus coronata (Mart.) Becc.	Arecaceae
Syagrus romanzoffiana (Cham.) Glassman	Arecaceae
Symphoricarpos orbiculatus Moench	Caprifoliaceae
Tamarindus indica L.	Leguminosae
Tamarix chinensis Lour.	Tamaricaceae
Taxodium distichum (L.) Rich.	Cupressaceae
Tecoma capensis (Thumb.) Lindl.	Bignoniaceae
Teucrium fruticans L.	Lamiaceae
Thuja occidentalis L.	Cupressaceae
Thuja plicata Donn ex D.Don	Cupressaceae
Tilia americana L.	Malvaceae
Tilia tomentosa Moench	Malvaceae
Trithrinax campestris (Burmeist.) Drude & Griseb.	Arecaceae
Tsuga canadensis (L.) Carrière	Pinaceae
Ulex parviflorus Pourr.	Leguminosae
Ulmus americana L.	Ulmaceae
Ulmus glabra Huds.	Ulmaceae
Vesalea floribunda M.Martens & Galeotti	Caprifoliaceae
Viburnum odoratissimum Ker Gawl.	Adoxaceae
Viburnum rhytidophyllum Hemsl.	Adoxaceae
Weigela florida (Bunge) A.DC.	Caprifoliaceae
Yucca gigantea Lem.	Asparagaceae
Zelkova carpinifolia (Pall.) K.Koch	Ulmaceae