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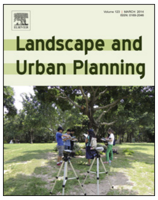

Research Paper

Estimating the allergenic potential of urban green spaces: A case-study in Granada, Spain

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HIGHLIGHTS

- The Allergenicity Index is a useful tool for estimating allergenicity in urban green spaces.
- The index highlights diversity as a key aspect of green spaces design.
- Adequate management and maintenance of green areas is a way of mitigating allergenicity.
- The index can be used for the planning, design and management of urban green spaces.

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ABSTRACT

A new quantitative index for estimating the allergenicity of tree species in urban green spaces takes into account allergenic potential, pollination strategies, duration of the pollination period, tree size and number of individuals per species as intrinsic parameters depending on the tree species concerned. Other factors analysed included the surface area occupied by each tree, with a view to calculating the overall percentage coverage of each allergenic species. The index is expressed as a ratio, thus enabling the design of an urban green space to be compared with a hypothetical space of similar characteristics and maximum allergenicity: the value to be obtained would thus lie between IUGZA = 0, for spaces with no allergenicity at all and IUGZA = 1 for spaces with maximum allergenicity. The expression of allergenicity by an abstract number facilitates comparisons and the index can be applied to green spaces sharing similar characteristics. A case study of Garcia Lorca Park, Granada, Spain, assessed the practical application of the index in a real-life situation. It was found that a 44.13% of the park' total surface area was occupied by species with moderate to elevated allergenic potential. Other key factor influencing the index is the presence of species whose pollen is classified as a major local allergen. The index may also be used as a management tool for evaluating certain aspects which may need to be modified in order to minimise their allergenic impact, including the presence of single-species stands, hedges, and tree screens, and the prevalence of male trees.

1. Introduction

The main functions of green spaces in urban areas can be divided into two major categories: the provision of recreational amenities, benefits and well-being; and the conservation, insofar as it is possible, of nature (Dobbs, Escobedo, & Zipperer, 2011; Escobedo, Kroeger, & Wagner, 2011; Lafortezza, Carrus, Sanesi, & Davies, 2009; Maruani & Amit-Cohen, 2007). The importance of urban parks and gardens has grown over the last few decades. They have assumed a key role in improving the quality of life of local residents, who perceive green spaces as generally enhancing well-being by improving health, reducing stress, and providing the setting for leisure pursuits (Annerstedt et al., 2010; Grahn & Stigsdotter, 2003; Lafortezza et al., 2009; Sanesi & Chiarello, 2006). They also play a key role in improving the environment through better air quality, landscape enhancement, and noise reduction (Benzeval, Judge, & Whitchcad, 1995; Hills, 1995; Jackson, 2003; Morani, Nowak, Hirabashi, & Calfapietra, 2011; Pacione, 2003; Ulrich, 1979). In short, they provide ecosystem services and functions which directly or indirectly improve the quality of life and the well-being of residents (Dwyer, McPherson, Schroeder, & Rowntree, 1992; Escobedo et al., 2011; Lafortezza, Davies, Sanesi, & Konijnendijk, 2013; Lyytimäki & Sipilä, 2009).

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Yet despite their undeniably beneficial effects on health, these spaces for human-environment interaction themselves generate certain adverse effects or ecosystem disservices which may impair the quality of life of urbanites as well as incurring economic, environmental and/or social costs (Escobedo et al., 2011; Lyytimäki & Sipilä, 2009). Pollen emission by higher plants during the pollination period is among the ecosystem disservices having the greatest impact: it affects human health, prompting an allergic response in around 30–40% of the world population (Bousquet et al., 2008; Pawankar, Canonica, Holgate, & Lockey, 2011), it contributes to biotic air pollution (Cariñanos, Galán, Alcázar, & Domínguez, 2007; Cariñanos, Galán, Alcázar, & Dominguez, 2008), and it carries enormous direct (Doctor costs, medications, diagnostic tests), indirect (loss of work and school days, premature retirement) and intangible (social costs, loss of quality of life) costs implications (Green & Davis, 2005; Reed, Lee, & McCrory, 2004). Some analyses of the economic burden of allergic rhinitis estimated a cost of US dollars 2–5 billions per year, if only direct costs are considered (Reed et al., 2004; Weiss & Sullivan, 2001). Much of the symptom-causing airborne pollen comes from the species most commonly used in urban forests and green areas (D'Amato, Cecchi, D'Amato, & Liccardi, 2010; Hruska, 2003; Nicolau, Siddique, & Custovic, 2005; Riedler, Eder, Oberfeld, & Schener, 2000).

The criteria used in selecting urban tree species are usually based on considerations such as their tolerance of urban environmental stress (Sjöman & Nielsen, 2010), their adaptability to local climatic conditions, their ready availability in nurseries throughout the world (Szaebo, Benedikz, & Randrup, 2003), ease of management, colour variability, sterility or low fruit production, harmlessness of cultivars, crown shape, originality (Gómez Fernández, 2011), and even their ability to mitigate air pollution (Beckett, Freer-Smith, & Taylor, 1998; Morani et al., 2011). By contrast, very little attention has been paid to the actual or potential allergenicity of ornamental species (Hruska, 2003; Seitz & Escobedo, 2012; Staffolani, Velasco-Jimenez, Galán, & Hruska, 2011; Thompson & Thompson, 2003), that is, the one or more symptoms induced after allergen (pollen grains) exposure, including sneezing, itching, nasal congestion and rhinorrhea (Bousquet et al., 2008; Pawankar et al., 2011; Skoner, 2001) In a recent paper reviewing the causes of the growing allergenicity related to urban green spaces, major factors identified included: the mass use of certain species, giving rise to large sources of monospecific pollen (Alcázar et al., 2004; Díaz de la Guardia, Alba, De Linares, Nieto-Lugilde, & López Caballero, 2006); botanical sexism in dioecious species, prompting discrimination against female plants, due to the problems they pose (fruit fall, insects or bad odour), and in favour of male plants which produce and release large amounts of pollen (Ogren, 2000, 2002, 2003); and the introduction of species whose allergenic potential is poorly documented or wholly unknown, that have subsequently given rise to new sensitisations (Cariñanos & Casares, 2011).

The role played by urban green spaces has changed over the years: their function has ceased to be merely decorative, and they have become an essential element in any sustainable city model (Chiesura, 2004). This being so, a number of measures need to be implemented in order to improve urban environmental conditions and minimise the adverse impact of these spaces on the quality of life of certain residents (Escobedo et al., 2011; Millenium Ecosystem Assessment, 2005; Nowak & Dwyer, 2000). This paper outlines a preliminary approach to estimating the allergenic potential of urban green spaces in general, covering parks, gardens, woodlands, green corridors and street trees (Davies, MacFarlane, McGloin, & Roe, 2006; Lafortezza et al., 2013), based on the biological characteristics of the plant species and factors involved in their activity as sources of pollen emission. These include intrinsic, species-related factors as well as other factors associated with landscaping, such as the selection of species size and the relative proportion of open and tree-covered surface areas, all of which influence pollen dispersal. The Allergenicity Index described here can be used as a tool for selecting the best and most suitable plant species for inclusion in new green areas, by enabling the allergenic potential of a given design to be identified before this is implemented. The index can also be applied to existing green areas as a means of evaluating current allergenicity, and as a management tool enabling corrective measures to be adopted wherever risk situations are perceived. Finally, the index can be used to compare the allergenic potential of different spaces, regardless of their size or design. To illustrate the practical application of the index, a case study was carried out in an urban park in the city of Granada, in south-eastern Spain. The Potential Allergenicity Index was calculated, and measures were devised to minimise the adverse impact of the park on local residents and visitors.

2. Materials and methods

2.1. Allergenicity index

The index was based on the following theoretical principles:

1. Plant species used for ornamental purposes in urban landscapes (parks, gardens, tree-alignments or open green spaces in a broad sense) are the most common cause of pollen allergies among the local population.
2. The allergenic potential of most plant species used in urban landscaping is documented and available via bibliographical databases and specific journals (Mari, Rosi, & Palazzo, 2009; Ogren, 2002).
3. Pollen-release intensity in wind-pollinated species is linked to plant size (trees and shrubs) and ground cover (e.g. carpet species); greater crown volume means greater pollen release, since larger species tend to have more branches, blossoms and stamens per unit of surface area (Friedman, 2009).
4. The amount of pollen released into the air is directly proportional to the number of individuals of a single species in any given area.
5. Where two species have similar allergenic potential, the species with the longer pollination period will prompt allergic symptoms over a longer interval, since newly-released pollen is added to already-existing airborne concentrations, thus extending the pollen load over a longer period.

Therefore, the worst-case scenario in terms of the allergenic potential of an urban space would clearly be a design involving one or more large, wind-pollinated species with high allergenic potential and a prolonged flowering period.

The index is constructed taking into account both the intrinsic characteristics of each species, i.e. those linked to its biological properties (i.e., sexual reproduction, pollination, flowering) (Wüster, 1998), and certain aspects of its activity as a source of allergenic particles, including plant type and number of individuals. Combination of these parameters yields the following Urban Green Zone Allergenicity Index (I_{UGZA}):

$$I_{\mathrm{UGZA}} = \frac{1}{378 S_{\mathrm{T}}} \sum_{i=1}^{k} n_i \times \mathrm{ap}_i \times \mathrm{pe}_i \times \mathrm{ppp}_i \times S_i \times H_i$$

where k = number of species, n_i = number of individuals belonging to the i-species, $\mathrm{ap}_i = 0$, 1, 2, 3, or exceptionally 4 for main local allergens (Allergenic potential of the i-species), $\mathrm{pe}_i = 1$, 2, 3 (Pollen emissions of the i-species in pollen grains/m^3 of air), $\mathrm{ppp}_i = 1$, 2, 3 (Duration – PPP-Weeks. Duration of the main pollination period of the i-species in weeks), H_i = Tree height of the i-species in m,

Table 1
Scale of values for species-intrinsic features (ap, pe and ppp) and biometric parameters used in constructing the Urban Green Zones Allergenicity Index.

Intrinsic parameters	Values
Allergenic potential (ap) (based on Cariñanos & Casares, 2011; Frenz, 1995; Galán et al., 2007; Ogren, 2002; Spieksma et al., 1992)	0 = non-allergenic 1 = low allergenicity 2 = moderate allergenicity 3 = high allergenicity 4 = main local allergens
Pollen emissions (pe) (Cariñanos et al., 2002a; Givninsh, 1980)	0 = only female-sex individuals 1 = Entomophilous 2 = Amphiphilous 3 = Anemophilous
Principal pollination period (ppp) (Garcia-Mozo et al., 1999; Prieto-Puga de la Mata, 1996)	1 = 1–3 weeks 2 = 4–6 weeks 3 ≤ 6 weeks

Biometric parameters	Values
Horizontal crown projection (trees/shrubs)	Small-diameter: <4 m Medium-diameter: 4–6 m Large-diameter: >6 m
Herbs (meadows, rose beds, lawn coverage, . . .)	m^2 of covered surface
Height (trees/shrubs) (Navés-Viñas et al., 1995)	Mean height attained at reproductive maturity depending on local bio climate zone. Simplified scale: 2, 6, 10, 14 m exceptionally 18 m
Herbs (turf, grass, lawn, . . .)	$H = 0.25$ m[a] (minimum height when these species are adequately maintained)

[a] Given the high allergenic potential of grasses and material produced during mowing, it is deemed advisable to consider the volume of pollen released as minimum as long as grasses are frequently maintained and mowed; this value can be increased where grasses are inadequately tended or mowed and where there is a greater presence of colonising/invasive species of known allergenicity.

S_i = Surface area covered by the i-species in m^2 and S_T = Total surface area of the park in m^2.

Constructing the index in the form of a ratio enables allergenic potential to be more easily estimated and compared with that of a putative space of a similar size, type and number of species, but with the highest possible allergenicity values. The main factors influencing the allergenic potential of a given space can thus be reduced to an abstract number, whose value ranges from a minimum of $I_{\mathrm{UGZA}} = 0$ for wholly non-allergenic spaces to a maximum of $I_{\mathrm{UGZA}} = 1$, for spaces recording maximum scores for all factors and parameters measured. Moreover, given that the aim is to estimate the park's maximum allergenic potential with a view to avoiding high-risk situations, those factors that might reduce the pollen output of individual species, such as health status, pruning, mowing or artistic trimming (topiary), are not taken into account. Each species is thus assumed to release the largest possible amount of pollen. Although a green space could in theory display maximum allergenicity (=1), in practical terms this is highly unlikely, given the presence of non-planted areas such as footpaths and avenues, and of non-allergenic species. All values greater than 0.5 may thus be considered indicative of high allergenicity.

The parameters involved in the formula, and the range of values assigned to each of them, are outlined below. In order to simplify calculations, scales were reduced to a 3-classes, i.e. from 1 to 3, or to a 4-classes, i.e. from 0 to 3. In some cases, the scale was expanded to include an even higher value in order to cater for potential exceptional situations in each area (Table 1).

Allergenic potential (ap) is the value assigned to each species was based on data provided in reports and by databases: Cariñanos and Casares (2011), Frenz (1995), Galán, Cariñanos, Alcazar, & Dominguez (2007), Mari et al. (2009), Ogren (2002), Spieksma, Nolard, Frenguelli, & Van Moerbeke (1992) and Trigo, Jato, Fernández, & Galán, (2008). The scale goes from 0 = null, for species reported to be non-allergenic, to 3 = high, for species identified as highly-allergenic. Exceptionally, as indicated above, a further value 4 was reserved for the main allergenic species in the study area, i.e. those having the greatest impact on local residents and prompting a high rate of sensitisation in the study area (D'Amato & Lobefalo, 1989).

Pollen emission (pe) refers to the species' pollination strategy. The minimum value (0) was assigned to female individuals of dioecious species (plants with male (staminate) flowers on one plant, and female (pistillate) flowers on another plant) that produce no pollen; the value (1) was assigned to insect-pollinated species, in which pollen emission is negligible except in the immediate vicinity (Cariñanos, Alcázar, Galán, & Dominguez, 2002a); the value 2 was assigned to species that may be insect- or wind-pollinated; the highest value (3) was assigned to wind-pollinated species, which produce and release large amounts of pollen in order to offset the limited efficiency of this pollination vector (Givninsh, 1980).

The main pollination period (ppp) is defined as a period starting when 5% of the annual sum of pollen is accumulated, and ending when 95% of the annual total has been accumulated (Garcia-Mozo et al., 1999). Since climate conditions have a varying effect on this parameter, values assigned should be adjusted to reflect the length of the flowering period in each area (Deák, Makra, Matyasovszky, Csépe, & Muladi, 2013). Here, the ppp for species growing in the Garcia Lorca Park was established on the basis of published data for the flowering periods of standard Mediterranean species (Prieto-Puga de la Mata, 1996) and on the pollen calendar for the city of Granada, developed using daily mean pollen data for over 10 years (Díaz de la Guardia, Alba, De Linares, & Nieto-Lugilde, 2003). Values from 1 to 3 were assigned as a function of the mean duration of the main pollination period (expressed as number of weeks), bearing in mind that a longer pollination period gives rise to a longer period of high airborne pollen counts, and thus to a greater likelihood of triggering symptoms in allergy-sufferers as well as cross-reactions with other pollen types.

The combination of these parameters, ap_i, pe_i and ppp_i, gives a potential allergenicity value for each of the species in a green space; the value ranges from 0 (for species scoring 0 for each parameter) to a maximum of 27, or even 36 if species considered major local allergens are included. This would be the value assigned, for example, to *Cupressus, Olea, Platanus, Betula, Fraxinus, Ulmus, Alnus, Populus, Poaceae* or *Salix*, tree species all known as major allergens in Mediterranean countries (Bousquet & Lobefalo, 1984; D'Amato & Lobefalo, 1989) or to meadows or pasturelands in which grasses (Poaceae) and ruderal species (Urticaceae, *Plantago*, *Rumex, Artemisia, Chenopodium*, Amaranthaceae) predominate and which are kept in a wild, rustic or untended state favouring flowering (Del Tredici, 2010).

In addition to establishing the intrinsic potential allergenicity of the species selected during park design, their pollen-release capacity as a function of morphotype (tree, shrub, grass), height and ground cover was also taken into account. The surface area (Si) occupied by each species was estimated from the maximum horizontal crown projection area (in m^2) for an adult individual. This information was obtained from published research into the standard size attained by species during reproductive maturity in a specific climate zone, here the Mediterranean zone (Navés-Viñas, Pujol Solanich, Argimon de Vilardaga, & Sampere Montlló, 1995).

The usual maximum size of an adult individual is also available in the literature on the various species involved. In the simplified method used for calculating the index, tree height (H_i) was estimated as the distance from the crown to the bottom of a cylinder simulating the tree. For single shrubs, hemisphere radius was considered equal to plant height, while shrubs trained as hedges, like grass species, were measured as a polyhedron whose base

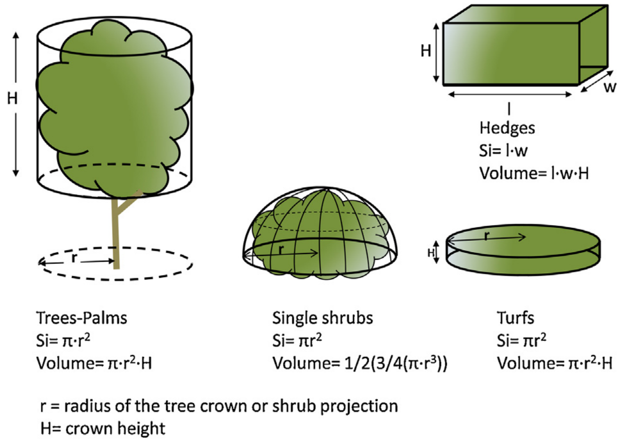

Fig. 1. Estimation of pollen emission capacity of trees, shrubs, hedges and lawns from the volume of a geometric figure like its morphotype.

Fig. 2. Map showing the location of Granada city.

was the area of the plot occupied, and whose height was that of the vegetation planted on the plot (Fig. 1). For fields and lawns, minimum height was taken to be 0.25 m; where these species were less carefully-tended or where the design envisaged their flowering, height values – and thus pollen-release capacity – were increased (rustic fields). The minimum height of 0.25 m was deemed to reflect the release of allergenic particles during mowing or, for untended fields, scything (Cariñanos, Alcázar, Galán, Navarro, & Dominguez, 2004).

To simplify calculations, tree heights were reduced to a scale of four values: 2, 6, 10 and 14 m. Exceptionally, as in the case of ap, an additional height value of 18 m was reserved to cover exceptionally high individuals (Table 1).

Finally, all these parameters were expressed with reference to the maximum potential allergenicity value that would be attained in a green space with a surface area similar to that studied (S_T), but where maximum values were recorded for every parameter (ap × pe × ppp = 27) and the maximum vegetation volume was reached (St × 14).

2.2. Description of the study area

The case study was carried out in the city of Granada, located in the southeast of the Iberian Peninsula (37°11′ N, 3°35′ W) (Fig. 2). The city covers a surface area of 88.02 km^2, and lies at an altitude of 738 m a.s.l., in a wide depression formed by the River Genil and the valley of the Sierra Nevada mountain range. This location gives rise to a continental Mediterranean climate, generally cool with freezing winters and hot summers, and with an average annual temperature of 15.1 °C, according to data for the period 1971–2000. Rainfall tends to be sparse, most occurring in winter: average annual rainfall for the same period was 357 mm (AEMET). Due to its geographical location and mild climate, the area boasts one of the widest ranges of plant species in the whole of Europe (Blanca, Cabezudo, Cueto, Fernández López, & Morales, 2009). The flowering periods of these species last over several months of the year (Alba, 1996). Recent research shows that the city of Granada has a total of 363 green spaces, of which 63 cover a surface area of over 5000 m^2. The city thus has 4.74 m^2 of green surface area per inhabitant (Gómez Lopera, 2005).

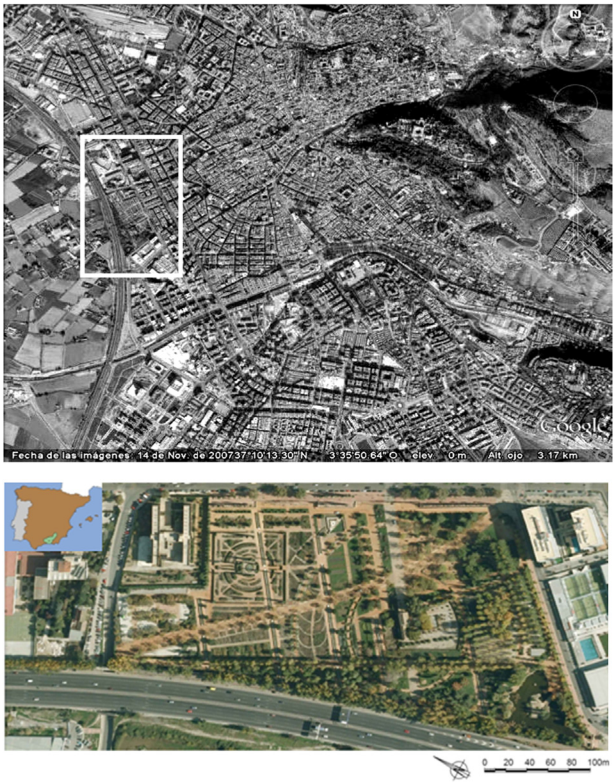

Fig. 3. Above: Urban map of Granada city and location of the Parque Garcia Lorca. Below: Aerial photo of Parque Garcia Lorca. Both images come from Google Earth.

One of the city's main green spaces and one of the most visited, the García Lorca Park, was selected for study. This park was selected because it is representative of Mediterranean city parks in terms of size, and because both species diversity and design are well-suited to illustrating the application of the index. The park, with a surface area of 71,500 m^2, is located to the south of the city, in an area known as the "Vega de Granada", an area of fertile plains devoted until recently to farming. It includes the "Huerta de San Vicente", land historically owned by the family of the poet García Lorca (Fig. 3).

The identification and quantification of species in the park was performed in situ over the course of numerous visits during the spring of 2012. Species were identified by means of the most widely-used keys: *Trees of Spain and Europe* (More & White, 2005), *Los árboles y arbustos de la Peninsula Ibérica y Baleares* (López González, 2006), *Arboles en España, Manual de Identificación* (López Lillo & de Lorenzo Cáceres, 2001). Plant sexuality was also taken into account, since for dioecious species it was essential to establish the exact number of male individuals actually contributing to the Green Zones Allergenicity Index. Data were also collected on the size, structure, design and predominance of relevant plant formations (e.g. single-species stands, living screens, tree-lined avenues), on species distribution, ornamental elements and lawn coverage. Additional data such as measurements of spaces (sidewalks, total surface area, buildings) was furnished by images and measurements obtained using field maps (Fig. 3)

2.3. Landscape and architectural features

In order to evaluate additional features that might influence the accumulation of pollen, consideration was given to: the design of the park itself; the presence of living screens; the formation of single-species alignments and the proximity between species able to establish cross-reactions. For this purpose, during field visits, the surface area occupied by these landscape and architectural features (in m^2) was recorded, and the location of the major allergenic species involved was marked on a field plan, in order to assess their behaviour as allergenic particle sources.

3. Results

The García Lorca Park in Granada was found to have an Urban Green Zones Allergenicity Index of 0.14. This value was obtained from the data collected for the park's 788 specimens of trees, shrubs and herbs, belonging to 77 taxa, and 32 botanical families (Table 2). Three of the families were Gymnosperms: *Pinaceae, Cupressaceae* and *Ginkgoaceae*, and the remainder were Angiosperms. *Cupressaceae* and *Rosaceae* were the most varied in terms of genera (9 and 7, respectively), whilst *Cupressus*, *Prunus* and *Populus* were the genera with most species (3 each). *Cupressus sempervirens* and *Ginkgo biloba* were some of the most abundant species (68 and 65 trees respectively), surpassed only by the 129 *Populus* trees, although these included several subspecies, hybrids and varieties. A number of species were represented by a single tree, among them *Abies pinsapo, Acer rubrum, Alnus glutinosa, Arbutus unedo, Cryptomeria japonica, Morus alba* and *Platanus hispanica*, whilst the greatest ground cover was recorded for species forming part of hedges, lawns and single-species living screens.

A total of 29 of the 77 species were associated with maximum allergenic potential, i.e. were widely known to trigger symptoms in allergy-sufferers (Table 2). These included all the species belonging to the *Cupressaceae* (*Cupressus arizonica, C. sempervirens* and *C. macrocarpa*), *Chamaecyparis lawsoniana, Cryptomeria japonica, Cupressocyparis leylandii, Sequoia sempervirens, Taxodium distichum* and *Thuja plicata*), as well as some of the major known allergens in Spain and Europe, such as *Betula pendula, Olea europaea, Platanus hispanica* and *Poaceae*. In some cases (e.g. *Cupressaceae, Morus alba*, *Acer* and *Poaceae*), allergenic potential is associated with a wind-pollination strategy, which prompts abundant pollen release. However, other species (e.g. *Pinaceae, Ginkgoceae* and *Mirtus*), whilst emitting a large amount of pollen, are not considered highly allergenic. For dioecious species, only males were considered allergenic; 80% of *Ginkgo biloba* individuals (52/65) and 93% of *Populus* individuals (120/129) belonged to exclusively-male hybrids and varieties (*P. alba* subsp. *pyramidalis*, and some *P.* × *euroamericana* clones) (Ogren, 2002).

A longer main pollination period is associated with longer exposure to allergens and thus with a greater likelihood of exacerbated allergy symptoms (Negro-Alvarez & Rodriguez-Pacheco, 2011). Some species growing in the park, including most of the Rosaceae, have short pollination periods (scarcely 2–3 weeks), while others (including *Laurus, Juglans, Citrus* and *Cupressus*) have pollination periods over 6 weeks long. In the case of lawn grasses and ruderal grassland, depending on the degree of maintenance – e.g. sporadic vs. routine mowing – the flowering period may be either long or short, due to the successive flowering of the different species involved and to the rapid response to water availability, in this case by irrigation (Del Tredici, 2010; Prieto-Baena, Hidalgo, Domínguez, & Galán, 2003).

The combination of the three parameters (allergenic potential, pollen emission and main pollination period) yielded a value lying between 0 and 36, which indicated the potential intrinsic allergenicity of each species. This value enabled species to be classified as being of low allergenicity (from 0 to 8), moderately-allergenic (from 9 to 17) or highly-allergenic (from 18 to 36). This latter group included the major species triggering allergic reactions in a high percentage of local pollen-allergy sufferers.

Another parameter taken into account when constructing the index was the surface area covered by each species, measured as the crown projection area of an adult specimen at its optimal reproductive stage, i.e. at age 15 in the case of trees. The park contained a number of large-diameter trees, with crown projection areas exceeding 10 m in diameter, among them *Cedrus deodara, Abies pinsapo, Picea abies, P. hispanica* and *Gleditsia triacantos.* Others were classed as small-diameter, e.g. *Lagerstroemia indica, Punica granatum, Prunus laurocerassus* and *Sambucus nigra*. In the case of shrub species, the greatest ground cover was recorded for certain Rosaceae (*Rosa, Chaenomeles*), distributed throughout the park, whose total ground cover was estimated at 6600 m^2, and for *Mirtus* and *Ligustrum* hedges (1000 and 1298 m^2, respectively) delimiting different zones of the design. The most striking finding for grasses was an area of 11,800 m^2 covered by lawns around a small lake in the south-east of the park (Fig. 3 below) Joint analysis of the surface area occupied by single species and the allergenic potential of those species showed that of the 37,247.4 m^2 total surface area covered by vegetation, an area of 31,559.4 m^2 was occupied by species with moderate to elevated allergenic potential, which thus accounted for 44.13% of the park's total surface area.

Estimation of pollen-release capacity for the various species on the basis of crown volume also yielded interesting results. As expected, the highest values were recorded for tall gymnosperms (*Abies, Cedrus, Sequoia, Taxodium)*, and for angiosperms over 10 m high, including *Aesculus, Robinia, Magnolia*, and *Platanus*. However, the greatest total volume was recorded for shrubs (e.g. *Rosa*) and grasses, due to extensive ground cover.

With regard to the landscape and architectural features of the park environment, it is worth highlighting the formation of plant screens at three sections of the park, with continuous rows of cypresses and thujas in the eastern section, *Ginkgo biloba* in the western section and *Populus* in the southern section, where they provide a visual and anti-noise screen against the nearby Granada ring road (Fig. 3 below). *Populus* also forms part of the tree-lined avenues that cross the park: the boulevard running parallel to the river, and the avenue of limes, with a majority of *Tilia* spp. There is a certain amount of single-species clumping, for example in the rose garden and some myrtle hedges.

4. Discussions

The Allergenicity Index obtained by applying the formula described above suggests that, in overall terms, the park has low allergenic potential, i.e. that it may be considered environmentally healthy, in that it does not pose a high risk for pollen-allergy sufferers. Pollen emissions from the species growing in the park do not therefore constitute an ecosystem disservice in terms of overall cost (Escobedo et al., 2011; Green & Davis, 2005; Lyytimäki & Sipilä, 2009). However, it should be borne in mind that while the maximum value for the index might theoretically be 1, this value is unlikely to be attained, at least in urban green areas designed on the basis of aesthetic and functional criteria rather than in an attempt to reproduce a natural setting. For that reason, the value obtained for the park studied here should be viewed within a context in

Table 2
List of Species in Garcia-Lorca Park and parameters: allergenic potential, pollen emissions and main pollination period.

No.	Species Trees volume = $\pi \cdot r^2 \cdot H_i$	Family	Allergenic Potential (ap)	Pollen emissions (pe)	Principal pollination Period (mpp-weeks)	Volume $S_i{}^*H_i$	Index of allergenicity of ecah species ($ap_i{}^*pe_i{}^*mpp_i{}^*S_i{}^*H_i$)	No. of Individuals in the park	Contribution of each species to I_{UGZA}
1	*Abies pinsapo*	*Pinaceae*	1	3	2	1099.56	6597.34	1	0.0002
2	*Acacia retinoides*	*Fabaceae*	2	1	2	169.65	678.58	12	0.0003
3	*Acer platanoides*	*Aceraceae*	3	3	2	502.65	9047.79	17	0.0053
4	*Acer rubrum*	*Aceraceae*	3	3	2	282.74	5089.38	1	0.0002
5	*Aesculus hippocastanum*	*Hippocastanaceae*	2	2	2	1413.72	11,309.73	5	0.0019
6	*Albizzia julibrissin*	*Fabaceae*	1	1	2	230.91	461.81	10	0.0002
7	*Alnus glutinosa*	*Betulaceae*	3	3	2	384.85	6927.21	1	0.0002
8	*Arbutus unedo*	*Ericaceae*	1	1	2	75.40	150.80	1	0.0000
9	*Betula pendula*	*Betulaceae*	3	3	2	282.74	5089.38	2	0.0003
10	*Cedrus deodara*	*Pinaceae*	2	3	3	2474.00	44,532.08	17	0.0260
11	*Celtis australis*	*Ulmaceae*	2	2	2	904.78	7238.23	2	0.0005
12	*Ceratonia siliqua*	*Fabaceae*	2	1	2	785.40	3141.59	2	0.0002
13	*Cercis siliquastrum*	*Fabaceae*	1	1	2	125.66	251.33	22	0.0002
14	*Citrus aurantium*	*Rutaceae*	1	1	3	25.13	75.40	11	0.0000
15	*Cupressus arizonica*	*Cupressaceae*	4	3	2	70.69	1696.46	4	0.0002
16	*Cupressus macrocarpa*	*Cupressaceae*	4	3	3	274.89	9896.02	17	0.0058
17	*Cupressus sempervirens*	*Cupressaceae*	4	3	3	56.55	2035.75	68	0.0048
18	*Chamaecyparis lawsoniana*	*Cupressaceae*	3	3	3	127.23	3435.33	4	0.0005
19	*Cryptomeria japonica*	*Cupressaceae*	3	3	3	70.69	1908.52	1	0.0001
20	*Cupressocyparis leylandii*	*Cupressaceae*	3	3	3	125.66	3392.92	5	0.0006
21	*Cydonia oblonga*	*Rosaceae*	0	1	3	75.40	0.00	6	0.0000
22	*Dyospiros kaki*	*Rosaceae*	1	1	1	117.81	117.81	2	0.0000
23	*Eriobothrya japonica*	*Rosaceae*	1	1	2	117.81	235.62	13	0.0001
24	*Ficus carica*	*Moraceae*	0	1	2	384.85	0.00	2	0.0000
25	*Fraxinus* spp.	*Oleaceae*	3	3	2	274.89	4948.01	5	0.0009
26	*Ginkgo biloba* (male)	*Ginkgoaceae*	2	3	2	692.72	8312.65	52	0.0149
26 b	*Ginkgo biloba* (female)	*Ginkgoaceae*	0	3	2	692.72	0.00	13	0.0000
27	*Gleditsia triacanthos*	*Fabaceae*	2	1	2	1099.56	4398.23	2	0.0003
28	*Juglans nigra.*	*Juglandaceae*	3	2	3	904.78	16,286.02	3	0.0017
29	*Juglans regia*	*Juglandaceae*	3	2	3	1413.72	25,446.90	6	0.0052
30	*Lagerstroemia indica*	*Lythraceae*	1	1	2	6.28	12.57	9	0.0000
31	*Laurus nobilis*	*Lauraceae*	3	1	3	42.41	381.70	16	0.0002
32	*Libocedrus decurrens*	*Pinaceae*	3	3	3	175.93	4750.09	32	0.0052
33	*Ligustrum* spp.	*Oleaceae*	3	2	2	274.89	3298.67	12	0.0014
34	*Magnolia grandiflora*	*Magnoliaceae*	1	1	2	703.72	1407.43	19	0.0009
35	*Melia azederach*	*Meliaceae*	1	1	2	384.85	769.69	6	0.0002
36	*Mirtus communis*	*Mirtaceae*	2	3	1	2.04	12.25	25	0.0000
37	*Morus alba*	*Moraceae*	3	3	2	282.74	5089.38	1	0.0002
38	*Olea europaea*	*Oleaceae*	4	3	2	282.74	6785.84	9	0.0021
39	*Pawlonia tomentosa*	*Meliaceae*	1	1	2	395.84	791.68	1	0.0000
40	*Picea abies*	*Pinaceae*	1	3	1	1413.72	4241.15	1	0.0001
41	*Punica granatum*	*Punicaceae*	0	1	3	6.28	0.00	14	0.0000
42	*Pinus halepensis*	*Pinaceae*	2	3	2	1413.72	16,964.60	10	0.0058
43	*Pinus pinaster*	*Pinaceae*	2	3	2	2035.75	24,429.02	4	0.0034
44	*P. hispanica*	*Platanaceae*	4	3	2	2035.75	48,858.05	1	0.0017
45	*Populus* spp. *(P. alba subsp. pyramidalis. P.* × *euroamericana)*	*Salicaceae*	3	3	2	175.93	3166.73	129	0.0140
46	*Phoenix canariensis. P. dactylifera*	*Arecaceae*	3	3	1	25.13	226.19	2	0.0000
47	*Prunus cerassifera*	*Rosaceae*	1	1	1	75.40	75.40	4	0.0000
48	*Prunus domestica*	*Rosaceae*	1	1	1	75.40	75.40	6	0.0000

Table 2 (*Continued*)

No.	Species Trees volume = $\pi \cdot r^2 \cdot H_i$	Family	Allergenic Potential (ap)	Pollen emissions (pe)	Principal pollination Period (mpp-weeks)	Volume S_i*H_i	Index of allergenicity of ecah species (ap$_i$*pe$_i$*mpp$_i$*S_i*H_i)	No. of Individuals in the park	Contribution of each species to I_{UGZA}
49	*Prunus laurocerassus*	*Rosaceae*	1	1	1	28.27	28.27	2	0.0000
50	*Pyrus communis*	*Rosaceae*	1	1	2	75.40	150.80	6	0.0000
51	*Quercus ilex* subsp. *ilex*	*Fagaceae*	2	3	2	904.78	10,857.34	1	0.0004
52	*Robinia pseudoacacia/rosea*	*Fabaceae*	2	1	2	538.78	2155.13	30	0.0022
53	*Salix* spp.	*Salicaceae*	3	3	2	282.74	5089.38	5	0.0009
54	*Sambucus nigra*	*Adoxaceae*	2	1	2	42.41	169.65	1	0.0000
55	*Schinus molle*	*Anacardiaceae*	3	1	2	169.65	1017.88	1	0.0000
56	*Sequoia sempervirens*	*Cupressaceae*	2	3	3	2035.75	36,643.54	2	0.0025
57	*Taxodium distichum*	*Cupressaceae*	3	3	3	2035.75	54,965.31	2	0.0038
58	*Tilia* spp.	*Malvaceae*	2	1	2	1583.36	6333.45	65	0.0141
59	*Tuya plicata*	*Cupressaceae*	3	3	3	157.08	4241.15	7	0.0010
60	*Ulmus pumila*	*Ulmaceae*	3	2	2	1099.56	13,194.69	2	0.0009
61	*Washingtonia* sp.	*Arecaceae*	1	3	2	100.53	603.19	1	0.0000
	Singles shrubs volume = 1/2(3/4($\pi \cdot r^3$))						0.00		0.0000
62	*Agave americana*	*Agavaceae*	0	1	1	1.18	0.00	2	0.0000
63	*Chaenomeles especiosa*	*Rosaceae*	0	1	1	1.18	0.00	20	0.0000
64	*Phormium tenax*	*Xanthorrhoeaceae*	0	1	1	3.98	0.00	10	0.0000
65	*Nerium oleander*	*Apocynaceae*	2	1	2	3.98	56.55	23	0.0000
66	*Syringa vulgaris*	*Oleaceae*	2	1	2	1.18	25.13	6	0.0000
	Cliped hedges volume = $S_i \cdot H_i$						0.00		0.0000
67	*Buxus sempervirens* (hedge)	*Buxaceae*	0	1	1	50.00	0.00	1	0.0000
68	*Cupressus semp.*(hedge)	*Cupressaceae*	4	3	3	800.00	28,800.00	1	0.0010
69	*Euonymus* sp. (hedge)	*Celastraceae*	0	1	1	180.00	0.00	1	0.0000
70	*Ligustrum vulgare* (hedge)	*Oleaceae*	3	2	2	1080.00	12,960.00	1	0.0004
71	*Mirtus communis*(hedge)	*Mirtaceae*	2	3	1	600.00	3600.00	1	0.0001
72	*Pittosporum tobira* (hedge)	*Pittosporaceae*	0	1	1	120.00	0.00	1	0.0000
73	*Rosa* spp.	*Rosaceae*	1	1	1	17,000.00	17,000.00	1	0.0006
74	*Xantolina chamaecyparissus*	*Asteraceae*	1	1	1	50.00	50.00	1	0.0000
75	Various flower shrubs and hedges	Various	0	1	3	450.00	0.00	1	0.0000
	Turf and flowers beds volume = $S_i \cdot H_i$								
76	*Lolium* sp. *Poa* sp. etc.	*Poaceae*	4	3	3	2950.00	106,200.00	1	0.0036
77	Various flower beds	Various	0	1	3	350.00	0.00	1	0.0000

The table also shows the Intrinsic Allergenicity of each species and their contribution to the index of Allergenicity of the Park (I_{UGZA}) as a function of their volume and number of individuals. S_i: Surface area covered by the i-species in m^2, considering its morphotype (trees, shrubs, hedges or turf). H_i: Size of the species in m. For grasses and herbs, the standard size was generally taken as 0.25 m.

which a value of 0.5 is already high enough to trigger problems in allergy-sufferers. It should also be stressed that this index value is the result of a combination of factors intrinsic to the species themselves but also reflects their prevalence in a given space. This may represent a valuable supplement to other current multifactorial scales used to determine allergenicity. Such scales take into account a number of parameters linked to the biology and phenology of a given species, including: pollination strategy, phylogeny, length of flowering, specific gravity, dryness or stickiness of the pollen grains, size, shape, colour and fragrance of the flower, position on the plant, and even life-cycle (Ogren, 2000, 2002; Hruska, 2003). However, the resulting value is applied individually to each single species, without reference to the fact that it may be growing in a space shared by other species, establishing relationships among them, as part of a specific design on a given surface area. Those considerations are taken into account with the index proposed here. It should also be noted that the simplified scale used in this index provides information on the specific weight of each parameter, on the contribution of the most common local allergenic species, on plant sexuality and representativeness, and on pollen-release capacity as a function of morphotype. In the park studied here, for example, the value reflected the contribution of non-allergenic and scarcely-allergenic species (*Albizzia julibrissin, Cercis siliquastrum, Cydonia oblonga, Magnolia grandiflora* and *Prunus cerassifera*, among others), as well as species with maximum allergenic potential in the Mediterranean area (*Olea europea, Cupressus sempervirens, P. hispanica.* grasses). At the same time, it reflected the contribution both of abundant species (*Populus* spp., *Robinia pseudoacacia, Tilia* spp.), and of species which, though less abundant, covered large surface areas of the park due to their individual size (*Cedrus deodara, Ginkgo biloba*) as well as single-species (hedges, rose-gardens) or multiple-species groups (e.g. fields) with extensive ground cover.

One of the key factors influencing the Allergenicity Index is the presence of species whose pollen is classified as a major local allergen. This is the case of *Olea europaea* in the Mediterranean region (D'Amato, Cecchi, et al., 2007a; D'Amato, Spieksma, et al., 2007b), which recorded the highest score for allergenic potential. Since there were only 9 olive trees in the Garcia-Lorca park, and since emission can be diluted by air currents (Cariñanos et al., 2002b), high pollen counts were not recorded. However, in designing parks, care must be taken to avoid the excessive planting of other Oleaceae species in the vicinity of olive trees, even though they are insect-pollinated, as cross-reactions may occur due to the presence of shared Oleaceae allergens (Martin Orozco et al., 1994; Pajarón et al., 1997). Similarly, privet shrubs (*Ligustrum* spp.) should be kept to a minimum, because symptoms are experienced only in the immediate vicinity, since pollen grains are not transported far from the source (Cariñanos et al., 2002a). Caution should also be exercised with regard to certain commercial varieties of *Fraxinus* species marketed as "seedless", because they are in fact male or polygamous species which emit a large amount of pollen (Cariñanos & Casares, 2011; Ogren, 2002). A similar situation can arise with London planes (*P. hispanica*). When there are few of these in the green area, their allergenic impact is sparse; however, if they are widely grown they may prompt considerable allergy problems (Alcázar et al., 2004; Gabarra, Belmonte, & Canela, 2002; Sabariego-Ruiz, Gutierrez Bustillo, Cervigon Morales, & Cuesta, 2008). Another species with high allergenic potential is *Laurus nobilis*, of which the park contains 16 widely-scattered individuals; however, regular clipping and pruning helps to avoid excessive flower production and thus excessive pollen release, which is also limited by the fact that it is an insect-pollinated species. The same is true of the myrtle or "arrayán" (*Mirtus communis*), which may be involved in hay fever attacks if hedges are not clipped and pruned on a regular basis and are allowed to flower (Ogren, 2002).

Species scoring maximum points for pollen emission included all the Gymnosperms (*Pinaceae, Cupressaceae* and *Ginkgoceae*) and the anemophilous Angiosperms, such as *Acer, Alnus glutinosa, Betula pendula, Mirtus communis, Morus alba, Populus spp., Platanus, Phoenix* and Poaceae (Givninsh, 1980). In many of these species, pollen production per anther can exceed 10,000 grains (Piotrowska, 2008; Prieto-Baena et al., 2003; Tormo Molina, Muñoz Rodriguez, Silva Palacios, & Gallardo Lopez, 1996); this massive production serves as a means of offsetting the limited effectiveness of wind pollination. Therefore, it is advisable to limit the number of individuals using this pollination strategy in any given area, in order to avoid creating a large, concentrated pollen source, and to enable pollen grains to be diluted by air currents (Cariñanos et al., 2002b; Jones & Harrison, 2004).

Duration of the main pollination period also plays a key role in this respect. The pollination period of most of the species in the park ranges between 1 and 6 weeks, leading to a heavy pollen load over a very specific period. However, since this period includes flower opening, anther maturation, pollination and fruiting (Prieto-Puga de la Mata, 1996), the actual duration of pollen emission is shorter, and thus the scope for triggering symptoms in allergy-sufferers is more limited. As mentioned previously, the meteorological parameters have a great influence both the onset and the length of the flowering period of the species in different biogeographic areas (Garcia-Mozo et al., 1999; Staffolani et al., 2011), so classes established for this parameter should be adjusted in relation to the climatic characteristics of each area.

It is important to establish the timing of pollination in the species concerned. With the exception of *Cupressaceae*, whose different species flower successively, with overlapping pollination periods, and for certain winter-flowering taxa such as *Fraxinus* and *Acer* (Díaz de la Guardia et al., 2006), most of the species in the park are spring-flowering, making spring the most adverse time for allergy-suffering park visitors. As the value obtained by applying the index does not distinguish seasonal periods, but the permanent specific composition of green space, it would be useful to provide additional information on the possible risk of staying too long in the park in certain periods/seasons of the year. This could be achieved by publishing aerobiological data from a nearby sampling station, if available.

Another useful piece of information to include in the Allergenicity Index is the proportion of the total surface area covered by allergenic species, and their distribution in the park. In the present study, crown projection diameter of trees and shrubs was taken as input datum. To ensure an optimum value for this data, the greatest size reached by the species at reproductive maturity should be used. It is at this stage that the individual has most branches, blossoms and stamens per unit of surface area. For groups or herbaceous species covering a large surface area, the whole group should be viewed as a single unit, taking projection as the total surface area occupied. In the park studied here, many species displayed a minimal area of cover, being represented by a single individual (*Morus alba, Sambucus nigra*) or by a larger number of individuals with crown projections of less than 4 m (*Citrus auriantium, Cupressus sempervirens, Lagerstroemia indica, Populus* spp. and *Punica granatum*).

The estimation of the pollen-release capacity of different species is a novel supplement to morphotype information, both of which help to regulate the contribution of each species to the overall index. Simulation of trees as a cylinder whose radius is equivalent to half the crown projection diameter usefully accounts for a range of findings, including the high pollen emissions by *Cupressus*, whose small crown diameter is offset by peripheral cones located anywhere on the tree, from the base upwards (Hidalgo & Galán, 2000), or those of leafy species with larger crowns, in which reproductive structures are not always located on the peripheral surface

(Friedman, 2009). The hemispherical assimilation applied to shrubs takes into account that pollen is released by flowers arranged on numerous stems sprouting from the base of the shrub (Costermans, 2009). The varying value assigned to grasses as a function of the degree to which they are tended may have a significant influence on their final contribution to the Allergenicity Index.

It is quite possible that two different taxa will have the same species Allergenicity Index (Table 2). In the case of *Populus*, for example, the AI value reflects the large number of individuals, each with a projection diameter of 4 m. or less. By contrast, the same AI value for *Tilia* reflects a considerably smaller number of individuals, but with a large crown projection diameter. In both cases, the originally-moderate allergenicity may be increased due to their abundance (Derbes, 2004; Mur et al., 2001; Pujevic, 1959) or to the use of only male specimens (Ogren, 2003). This highlights the importance of taking into account, when selecting species as part of a landscape design, whether species are monoecious or dioecious, and in the latter case whether only male plants are to be used; this decision will have a marked effect on overall allergenicity values. A good example is furnished by *Ginkgo biloba*. This Gymnosperm, introduced into Europe from China and long considered a living fossil, has become widespread in many cities because of its good adaptability to urban climate conditions and its spectacular flabellate leaves which turn golden in autumn (Cothran, 2004). However, the widespread preference for male individuals with a view to avoiding the nuisances associated with females – such as the unpleasant butyric-acid smell given off by the fruits – led to an excessively high proportion 80% of males, which accounted for 52 of the total 65 ginkgos in the park. Moreover, the proven allergenicity of ginkgo pollen (Del Tredici, 2007; Yun, Si-Hwan, Jung-Won, & Chein-Soo, 2000), together with high pollen production (Amores Jordán, 2011), make this one of the species contributing most to the park's total Allergenicity Index.

The landscape and architectural features of the park environment may also influence its overall allergenicity. All possible landscape elements using plant species are to be found in the Garcia-Lorca Park. Of particular note are the formation of living screens on three of its sides, and the use of tree-lined avenues and single-species designs. The concentration of individuals with a high species Allergenicity Index may influence the overall value for the whole space, particularly if they cover a large surface area. Noteworthy in the park studied here were the continuous rows of cypresses and thujas, the anti-noise screen composed of *Ginkgo* and *Populus* and the tree-lined avenues of *Populus* and *Tilia* that cross the park. Herbaceous species also contributed strongly to the overall index, especially those forming extensive lawns or fields. This contribution is strongly influenced by the extent and frequency of garden management and maintenance. Frequent adequate mowing would impede flowering, thus minimising the contribution of grasses to the overall index. By contrast, inadequate management due to limited resources or to the reduction of existing resources as a result of the current economic situation (Hammer, Kamel-Chaui, Robert, & Plomin, 2011), or in areas where natural- or rustic-looking meadow grasses are allowed to flower, their contribution to the Allergenicity Index may be increased, given the considerable allergenic potential of grasses worldwide (D'Amato, Spieksma, et al., 2007; Freidhoff, Ehrlich-Kantzky, Grazt, Meyers, & Maish, 1986) and the successive flowering of different individuals and species (Prieto-Baena et al., 2003). The same is true of spontaneous and invasive species that may be found scattered over the surface area, some of which display allergenic capacity, among them *Parietaria*, Amaranthaceae, Asteraceae (*Artemisia, Ambrosia*) and others (Ferrer et al., 2012; Stumvoll et al., 2003). Where the presence of these species is continuous and not controlled by maintenance activities, ground cover should also be taken into account just as it is with meadow species. Other design and landscape features, such as lakes, ponds and watercourses, help to regulate pollen levels by preventing pollen grains deposited on the ground from returning into the air through resuspension, and by increasing environmental humidity, facilitating in turn the deposition process (Lacey & West, 2006).

Lastly, the built-up environment of the park also has to be borne in mind, since it determines the extent to which biological particles emitted both inside and outside the park can join the airflow and thus be dispersed, thereby avoiding the build-up of excessive concentrations. On one hand, the presence of buildings in the environs of the park might at times restrict the dispersal of endogenous material, since pollen concentrations are not distributed uniformly once they are incorporated into the air flow (Cariñanos et al., 2002b). On the other hand, the park is located in the south of the city, at the foot of the Sierra Nevada Massif, which facilitates frequent air renewal, thanks to the local valley-mountain breeze system, (Emberlin, 1994). A further consideration is that the surrounding environment may itself be the original source of other particles that increase existing concentrations. This could be the case of biological material from nearby natural and/or cultivated vegetation, and the non-biological solid particles arising from the combustion of hydrocarbons used mainly in diesel combustion vehicles. Both these factors could lead to a worsening of air quality in the vicinity of the park, and symptoms could be exacerbated particularly by the joint effect of various different kinds of particles (Cariñanos et al., 2008; Kalbande, Dhadse, Chaudhari, & Wate, 2008; Muranaka et al., 1986). However, these factors cannot be taken into account in the index, since it is based on the species composition of the park design rather than on material originated outside of it. It is therefore a simple index enabling the elements within the park to be evaluated, and also enabling comparisons with other green spaces whilst avoiding the inclusion of parameters which are difficult to estimate and evaluate. As indicated earlier, data on local airborne particle content in the park area would provide supplementary information of particular interest to pollen-allergy sufferers, thus promoting the general well-being of the citizens.

5. Conclusions

The Allergenicity Index outlined here is a useful tool for estimating the allergenic potential of urban green spaces, and for quantifying the ecosystem disservices caused by airborne and local pollen emissions. This index highlights diversity as a key aspect of park design, in terms of minimising allergenic potential. Taxonomic (genera and species), morphological (size, shape), and biological diversity (pollination strategies, pollination periods) can help to minimise the impact of highly-allergenic species. The index can also be used to encourage corrective measures in specific areas of the park suspected of being highly allergenic; these might include avoiding the planting of mainly male trees in dioecious species, the use of singles species to form hedges or to line avenues, and the establishment of cross reactions between species belonging to the same family, and even the replacement of certain species in cases of serious risk. The findings also highlight the importance of adequate management and maintenance of green areas, as a way of mitigating the allergenicity of species requiring frequent pruning or mowing. The expression of allergenicity in terms of an abstract number facilitates comparisons and enables the application of the index to green spaces sharing similar characteristics, even in other geographical areas. However, since this is a first approach to estimating the allergenicity of urban green spaces, some of the constraints affecting the index should be remarked on and be considered in future research. Chief among these is the emission of pollen and other contaminants in the area surrounding the green space. This was deliberately excluded from the index, because it was not attributable to park design and because further specific research would be required into the possible local sources of emission as well as the atmospheric dynamics of the area concerned. Clearly, if the park is located in a highly-contaminated area, the allergenic effects of park vegetation are likely to be enhanced. Also the role of the meteorological parameters (temperatures, precipitation and winds) should be analysed in depth given its influence on biological parameters entering in the index. And finally, should be defined better the seasonal character that can have the index value in areas where the timing of pollination of the majority of the species is subject to a certain period of the year, as happens in marked contrast in climate areas.

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