



Estimating the allergenic potential of urban green areas in the city of Madrid (Spain)

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Abstract Urban green spaces offer large environmental, social, and economic benefits for the population. However, when species that compose it are chosen, its allergenicity is not usually considered, which poses a risk to the population with pollinosis. In this work, the potential allergenicity index (I_{UGZA}) of five urban parks in the city of Madrid (Spain) has been calculated, in order to assess their allergenic potential and to identify the species that most contribute to increasing it. The results show that three of the parks register an index value sufficient high to cause adverse reactions in the exposed population. The most contributing species to the index value are London plane (*Platanaceae* family), horse chestnut (*Sapindaceae*

family), pines and cedars (*Pinaceae* family), and various species of the Cupressaceae family. Some parks showed a relationship between tree density and percentage of species with high or very high potential allergenicity value (VPA), with the I_{UGZA} . A relationship between grass coverage and the percentage of contribution to the value of the index has been observed. These studies can guide managers in the selection of species with low allergenicity and management practices in order to minimize the effects on allergic citizens.

Keywords Urban parks · Allergenic flora · Allergenic potential · Index of allergenicity · Pollen allergy

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1 Introduction

Air pollution, urban warming, and extreme temperature episodes in summer and winter are some of the problems facing cities today. In this context, urban green infrastructure stands out as a key element for the provision of ecosystem services that generate well-being and benefit the population (Lafortezza et al., 2009; Latinopoulus et al., 2016). There are many benefits that parks and gardens can bring to the citizens from a social, economic, and environmental point of view. Its main functions include mitigating the effects

of the urban heat island and air pollution, capturing atmospheric CO₂, soil conservation, noise reduction, pollination functions, increasing biodiversity, and reducing floods and runoff. Additionally, there are other social and cultural benefits which are necessary for human health and well-being (Laforteza et al., 2013; Pleasant et al., 2014; Soga et al., 2017; Twohig-Bennet & Jones, 2018; Tzoulas et al., 2007; Yan et al., 2012).

However, the biological and ecological functions developed by urban vegetation can also be the cause of negative effects or disservices that affect the health and quality of life of citizens. One of these effects is the falling of trees or branches in poor condition that can damage infrastructure or injure people (De Stefano & Deblinger, 2005). In addition, some green spaces can be habitats for rats, vectors, pathogens, or being insecure for humans (Dobbs et al., 2011). Another negative effect caused by urban vegetation is the decrease in air quality due to the emission of polluting substances. Among them, we highlight the emission of volatile organic compounds (VOCs) that act as precursor substances in the formation of photochemical pollutants such as ozone (Zhao et al., 2020), as well as the pollen emissions made by plants during the period of flowering, which are considered one of the main causative agents of adverse respiratory reactions in the population (Cariñanos & Casares-Porcel, 2011). It is estimated that 30% of the world population is affected by pollen allergies (Pawankar et al., 2011). In urban settings, this situation is aggravated by a series of factors which are as follows:

- Low diversity of species selected as ornamentals that have generated the massive use of some of these species, generating important sources of pollen emission (Cariñanos & Casares-Porcel, 2011; Lara et al., 2020).
- Management and maintenance of green spaces are not always adequate, which have led to both the emission of pollen and the installation of species of recognized allergenicity (Xin et al., 2007).
- The presence of atmospheric pollutants, which together with urban microclimatic conditions, has generated an interaction between compounds with the consequent worsening of air quality and aggravation of associated respiratory diseases (Cariñanos et al., 2021; Senéchal et al., 2015).
- The alteration of the reproductive biology of urban ornamental species as a consequence of local environmental factors (Zipper et al., 2016; Wohlfart et al., 2019).

If there is a cause leading to increased allergenicity of green spaces it has been non-consideration of the allergenic potential inherent in the different plant species when selecting plant material to be incorporated in parks, gardens, alignments and other green urban elements (Vogt et al., 2017). Due to this, among the main allergens that cause allergic reactions in the population are those derived from the pollen emissions of some of the main species of ornamental flora (Cariñanos et al., 2017).

Urban green areas are considered the main source of pollen allergen emissions. Therefore, those people with hay fever who visit these spaces can develop worsening allergy symptoms. An 11-year study carried out on the atmosphere of Madrid (Gutiérrez et al., 2006) reveals that well-represented pollen types such as *Platanus* (25.1%), *Cupressaceae/Taxaceae* (22.5%), *Gramineae* (7.5%) and *Olea* (3.5%), have a high prevalence in skin tests performed on patients with pollinosis (40, 56, 94, and 61%, respectively) (Cabrera & Subiza, 2018). Regarding the maximum pollination levels, *Gramineae* and *Olea* reach their optimum in May and June, *Platanus* from mid-March to mid-April and *Cupressaceae/Taxaceae* from January-March (Alonso et al., 2011; Gutiérrez et al., 2001). Although the analysis of the pollen content of the atmosphere constitutes a risk prevention measure for allergy sufferers, sometimes they do not represent the real risk situations at the local level that is, the one that derives from the citizen's proximity to the emitting environment, which are usually the green spaces closest to the places where their daily routine takes place (Takano & Inoue, 2017). In other cities of central Spain (Toledo and Guadalajara), airborne pollen the ornamental plant such as *Cupressaceae* and *Platanus* also very abundant in the pollen spectrum (Lara et al., 2020; Rojo et al., 2016).

To estimate the potential allergenicity of any green space is used the potential allergenicity index of urban green zones (I_{UGZA}), proposed by Cariñanos et al. (2014). The index assesses the capacity of the ornamental flora to cause discomfort to people due to pollinosis. It is a quantitative index that considers both biological parameters of the plant species present

in the park (type of pollination, duration, and period of the pollination and allergenic potential), as well as certain aspects of their activity as sources of allergenic particles.

Studies on the calculation of the potential allergenicity index have been carried out in other parks in Spanish and European cities. In Spain, the works of Cariñanos et al. (2016) were carried out in 20 Spanish cities, Munuera et al. (2017) in Murcia, Lara et al. (2017) in Toledo, and Velasco-Jiménez et al. (2020) in Córdoba. In Europe (Germany), the work of Jochner et al. (2018), and Cariñanos et al. (2019) was carried out in urban parks of six Mediterranean countries. In the Community of Madrid, only a preliminary attempt of this type has been done (García-Ventura et al., 2019). We believe that these jobs are essential because they make it possible to identify green areas where air quality is most affected by the emission of allergenic pollen. They also guide managers on performance measures for the design and planning of new urban parks where the use of plant species is taken into consideration in order to have the greatest positive impact on the health of citizens.

In order to further strengthen the role of urban green infrastructure in the framework of sustainable and healthy cities, the aim of this work is to establish the potential allergenicity of five urban parks in the city Madrid by using the index of potential allergenicity of urban green zones (I_{UGZA}) (Cariñanos et al., 2014). The results of this work will identify the most influential variables on the potential allergenicity of these spaces and make suggestions for improvements that mitigate the impact on and improve the conditions for general users and allergy sufferers in particular.

2 Material and methods

2.1 Study area and selected parks

Madrid (40° 24' N, 3° 40' O) is located in the center of Spain at 667 m above sea level; it is large-size city with a surface of 604,45 km² and a population of around 3.266.126 inhabitants (INE, 2020). It is characterized by a Mediterranean climate with a continental trend. The average temperature is 15°C and annual rainfall is 421 mm (data from 1981 to 2010, AEMET- State weather agency).

The air pollution data for the city of Madrid during 2019 show very high levels, the most problematic being nitrogen dioxide (NO₂), particulate matter (PM10 and PM2.5), and tropospheric ozone (O₃) (Madrid Quality of the Air Report, 2019). Road traffic, followed to a lesser extent by emissions from airport landing and take-off and air conditioning systems are the main origins of pollution.

Madrid is a privileged city for its impressive green heritage of exceptional diversity; the city includes 1.500.000 trees distributed across more than 60 hectares of municipal green areas and 23 hectares of road trees (Borrajó et al., 2018). Madrid presents a density of 94 trees/hectares and approximately 26% of arboreal vegetation cover, data similar to those of other cities in the world, although the more than 500 different species rank it first in terms of urban tree diversity. This woodland is distributed in the different types of green areas that make up the urban forest of Madrid, among which, due to their abundance and traditional connection with society, are botanical parks, public gardens, and historical gardens. In order of abundance, the main plant species that make up the urban trees of Madrid and that account for 75% of the total are *Pinus pinea* L., *Quercus rotundifolia* Lam., *Pinus halepensis* Mill., *Ulmus pumila* L., *Platanus hispanica* (Aiton) Willd., *Cupressus arizonica* Greene, *Sophora japonica* L., *Robinia pseudoacacia* L., *Celtis australis* L., and *Acer negundo* L. (Borrajó et al., 2018).

For this study, 5 urban parks in the city of Madrid have been selected: Alfredo Kraus, Atenas, Azorín, Berlin, and Emperatriz María de Austria (Fig. 1). The main characteristics of these parks are shown in Table 1. They are parks for daily use and frequented regularly by citizens due to their location in residential areas (Alfredo Kraus, Azorín, Berlín and Emperatriz María de Austria) for sports activities, walking, children's games, or because of its proximity to the historic center of the city (Atenas).

The vegetation inventories of these public parks have been provided by the General Subdirectorate of Green Areas of the Madrid City Council, which are collected in a database compatible with geographic information systems (GIS), and updated in 2019. Additionally, the data referring to the surface and composition of the existing lawns or meadows have also been taken.



Fig. 1 Geographical location of the green spaces in the city of Madrid

In this work, the index of potential allergenicity of urban green zones (I_{UGZA}) proposed by Cariñanos et al. (2014) was used to estimate the potential allergenicity of the parks selected. This index assesses the capacity of the ornamental flora to produce symptoms of pollinosis in the people who visit these places in the periods when the allergenic species are in bloom. It is a quantitative index that considers both biological parameters of the species themselves, as well as biometric parameters, according to the following formula: Where: S_T = surface area of the urban park, K = number species in the park, n_i = number of individuals belonging to one species, VPA = potential allergenicity value for each species; ap_i (allergenic potential), ep_i (type of pollen emissions) and ppp_i (principal pollination pollen) (Table 2), S_i = area occupied by each species, H_i = maximum height reachable by mature tree, VPA values for the existing species in each park will be extracted from the Parameter Database for the calculation of the potential

allergenicity index (SafeCreative code 1,803,156,149,680, IPR-684). Since it is a potential index, both the surface (S) and height (H) values refer to the maximum that each species can reach at reproductive maturity, and which have been adjusted in the classes presented in Table 2.

$$I_{UGZA} = \frac{1}{\max VPA \times S_T} \sum_{i=1}^K n_i \times \underbrace{ap_i \times ep_i \times ppp_i}_{VPA} \times S_i \times H_i$$

The sum of the partial indices of the different species present in the park corresponds to the potential allergenicity index. The I_{UGZA} provides a standardized value between 0 and 1, establishing at 0.3 the threshold from which the flora of the green space can cause discomfort in the allergic population. This reference value was established by the authors of the index after analyzing the results obtained after applying the Index

Table 1 Main characteristics of the green spaces considered in this study

Parks/district	Surface (m ²)	Grass surface (m ²)	No Trees	Density (Trees/ha)	No species	Main species (No individuals)
Alfredo Kraus (Hortaleza)	38.580	11.634	822	213.0	38	<i>Platanus hispanica</i> (70) <i>Prunus cerasifera</i> var. <i>pissardii</i> (69) <i>Pinus pinea</i> (53) <i>Aesculus hippocastanum</i> (48) <i>Thuja plicata</i> (48)
Atenas (Centro)	46.472	22.733	815	175.4	52	<i>Sophora japonica</i> (248) <i>Gleditsia triacanthos</i> (129) <i>Aesculus hippocastanum</i> (66) <i>Robinia pseudoacacia</i> (36) <i>Ulmus pumila</i> (33)
Azorín (Vallecas)	47.434	31.026	694	146.3	34	<i>Pinus halepensis</i> (115) <i>Aesculus hippocastanum</i> (75) <i>Cupressus arizonica</i> (71) <i>Magnolia grandiflora</i> (59) <i>Populus alba</i> var. <i>bolleana</i> (55)
Berlín (Chamartín)	49.116	21.934	770	156.8	35	<i>Aesculus hippocastanum</i> (157) <i>Platanus hispanica</i> (122) <i>Populus alba</i> var. <i>bolleana</i> (100) <i>Prunus cerasifera</i> var. <i>pissardii</i> (86) <i>Pinus pinea</i> (78)
Emperatriz María de Austria (Carabanchel)	597.458	147,900	7995	135.5	82	<i>Pinus pinea</i> (2.288) <i>Ulmus pumila</i> (806) <i>Cedrus deodara</i> (189) <i>Cupressocyparis leylandii</i> (122) <i>Calocedrus decurrens</i> (53)

to green spaces with very different characteristics, in relation to typology, floristic composition, percentage of allergenic species, number of allergenic individuals on the total number of specimens, density of species and area occupied by allergenic species in the park (Cariñanos et al., 2014, 2017, 2019). The establishment of this threshold has in turn allowed different classes of allergenicity according to the following proposal: low value of potential allergenicity when the

I_{UGZA} value is below 0.2, moderate when the I_{UGZA} value is between 0.2 and 0.3, high when the value is between 0.3 and 0.5 and very high above 0.5 (Cariñanos et al., 2019).

Due to the importance of grass-forming Poaceae species as a worldwide allergen, we have calculated the contribution of grass coverage to the global allergenicity index. To calculate the contribution of lawns or meadows to the Index value, we have

Table 2 Scale of values for the parameters uses for I_{UGZA}

Parameters	Values for I_{UGZA}
Allergenic potential (ap_i)	0 = non-allergenic 1 = low allergenicity 2 = moderate allergenicity 3 = high allergenicity 4 = main local allergens
Type of pollen emissions (ep_i)	0 = only female-sex individuals 1 = entomophilous 2 = amphiphilous 3 = anemophilous
Principal pollination period (ppp_i)	1 = 1–4 weeks 2 = 5–8 weeks 3 = ≥ 9 weeks

considered the entire covered area as a single unit, which would be comparable to the base of a geometric figure. In a standardized way, we have considered a lawn height of 15 cm. Regarding VPA, it must be borne in mind that regardless of their composition, grasses are the main allergen worldwide, so in this case their allergenic potency has been considered rank 4, and the resulting VPA value is 36.

3 Results

The I_{UGZA} values obtained for the different parks are as follows: 0.57 in Alfredo Kraus Park, 0.25 in Atenas Park, 0.35 in Azorín Park, 0.56 in Berlín Park, and 0.27 in Emperatriz María de Austria Park (Fig. 2). Therefore, of the five parks studied and according to the authors of the index (Cariñanos et al., 2014), Alfredo Kraus and Berlín exceeded the threshold of

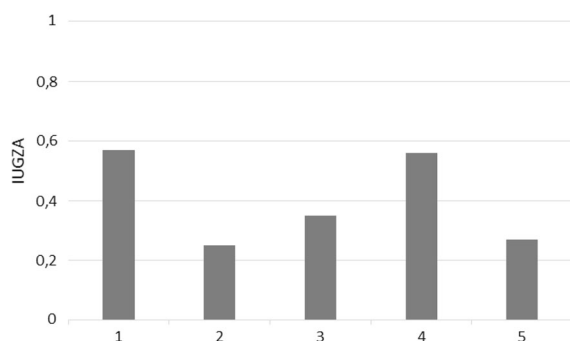


Fig. 2 I_{UGZA} of the urban parks considered in this study, according to the index proposed by Cariñanos et al. (2014)

the minimum risk value of 0.3. According to the risk classification scale established by the authors of the index, both parks exceeded the value of 0.5 which indicates a very high level of risk of potential allergenicity. Azorín had a high value, while the value for Atenas and Emperatriz María de Austria was moderate.

The species *Aesculus hippocastanum* L., with a VPA value of 12 (Fig. 3), contributed significantly to the potential allergenicity index in all parks, except in Emperatriz María de Austria. It was the species that contributed most in Atenas Park, second most in Berlín, and third most in Alfredo Kraus and Azorín (Fig. 4). *Platanus hispanica*, with a VPA of 18, was the species that contributed the most to increasing the index in Alfredo Kraus, Berlín, and Azorín despite the fact that the latter park had only a few individuals.

In Alfredo Kraus, 2 species of the Cupressaceae family (*Calocedrus decurrens* (Torr.) Florin and *Cupressocyparis leylandii* (AB Jacks. & Dallim.) Dallim.) had a high contribution to the index with 19 and 4%, respectively, due to their high VPA values (Fig. 3). However, these species were not among those with the highest number of individuals. These species also had an important contribution to the I_{UGZA} in Emperatriz María de Austria with a contribution percentage of 7 and 8%, respectively (Fig. 4). In both parks, the species of this family constituted one of the groups most at risk for people with pollinosis by emitting highly allergenic pollen with a very long period of presence in the air.

Species of the Pinaceae family (*Pinus pinea*, *Cedrus deodara* (Roxb. Ex D. Don) G. Don, *Cedrus*

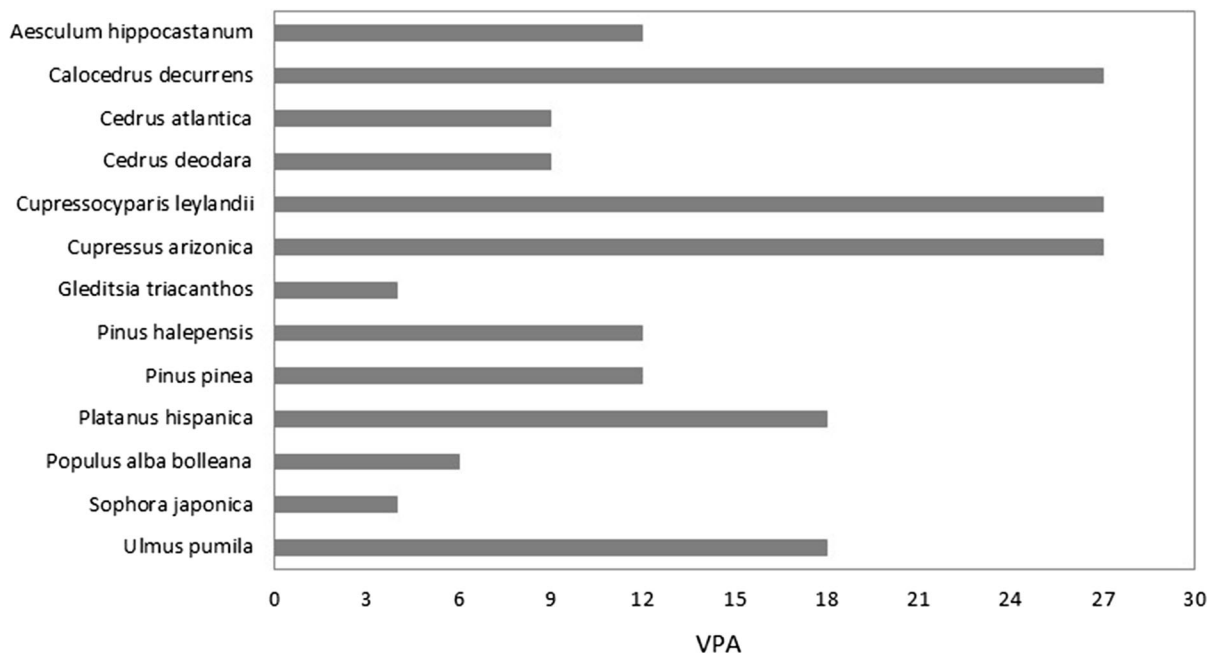


Fig. 3 VPA of the species with the highest contribution to the I_{UGZA} in the selected parks. VPA: pollination strategy x duration of pollination period x allergenicity of pollen grains (Cariñanos et al., 2014)

atlantica (Endl.) Manetti ex Carrière) with moderate VPA values (9–12) had a significant contribution to the index of potential allergenicity mainly in Azorín, Berlín, and Emperatriz María de Austria. In the latter, *Pinus pinea* is the species that contributed the most to the index with 32% of the total. *Cedrus atlantica* stood out in Berlin Park as the species that contributed the third most to increasing the index. In Azorín, *Cedrus deodara* was the second most significant species with a contribution of 20%.

In Atenas Park, species with a low VPA of 4, such as *Sophora japonica* or *Gleditsia triacanthos* L. (Fig. 3), had a significant contribution to the value of the index as were are the first and second most abundant species with a representation of 30.4 and 15.8%, respectively. In contrast, *Prunus cerasifera* var. *pissardii* (CarriSre) Dost, with a VPA of 1, despite being a very abundant species in Alfredo Kraus and Berlín, had a very low contribution to the index (below 0.07%). *Magnolia grandiflora* L. was a very well-represented species in Azorín Park, but with a very low contribution. Therefore, the species mentioned in the different parks were the ones that contributed the most to the value of the index, either due to the existence of a high number of highly allergenic species, or because these species were highly represented in the park.

Figure 5 shows the percentage of individuals with very high (27), high (18), moderate (12), low (1–6) and null (0) VPA for each park. It should be noted that Alfredo Kraus and Berlín had a similar I_{UGZA} but a very unequal percentage of individuals with very high and high VPA, with values of 53.7 and 36.1%, respectively. In Atenas Park, the percentage of individuals with low VPA was 60.7%, while in the rest of the parks this value was much lower (20–28.5%).

The parks with the highest tree density (trees/ha) were Alfredo Kraus and Atenas, while Azorín Park had the lowest (Table 1). Azorín had the highest grass coverage (65.4% of the total), followed by Atenas and Berlín, with 48.9 and 44.6%, respectively. In terms of the percentage of the contribution of the grass coverage to the index, Alfredo Kraus had the lowest value (0.54%) and Atenas and Azorín had the highest (1.86% and 1.79%, respectively).

4 Discussion

The total area of green space in the city of Madrid is 60,000,000 m² (Borrajó et al., 2018). In this study, we have analyzed a total area of 779,060 m², which represents 1.3% of the total. Despite being a low

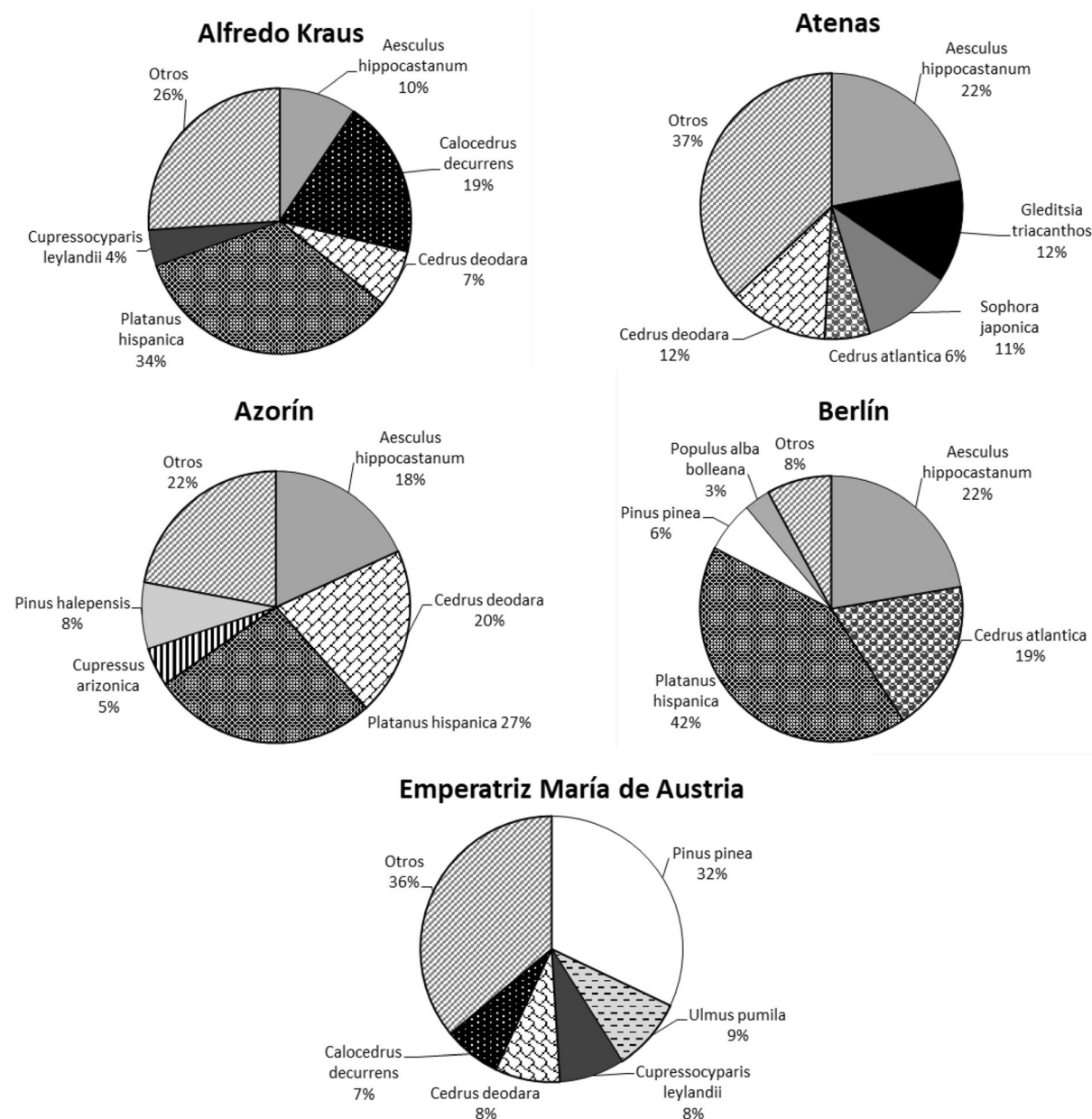
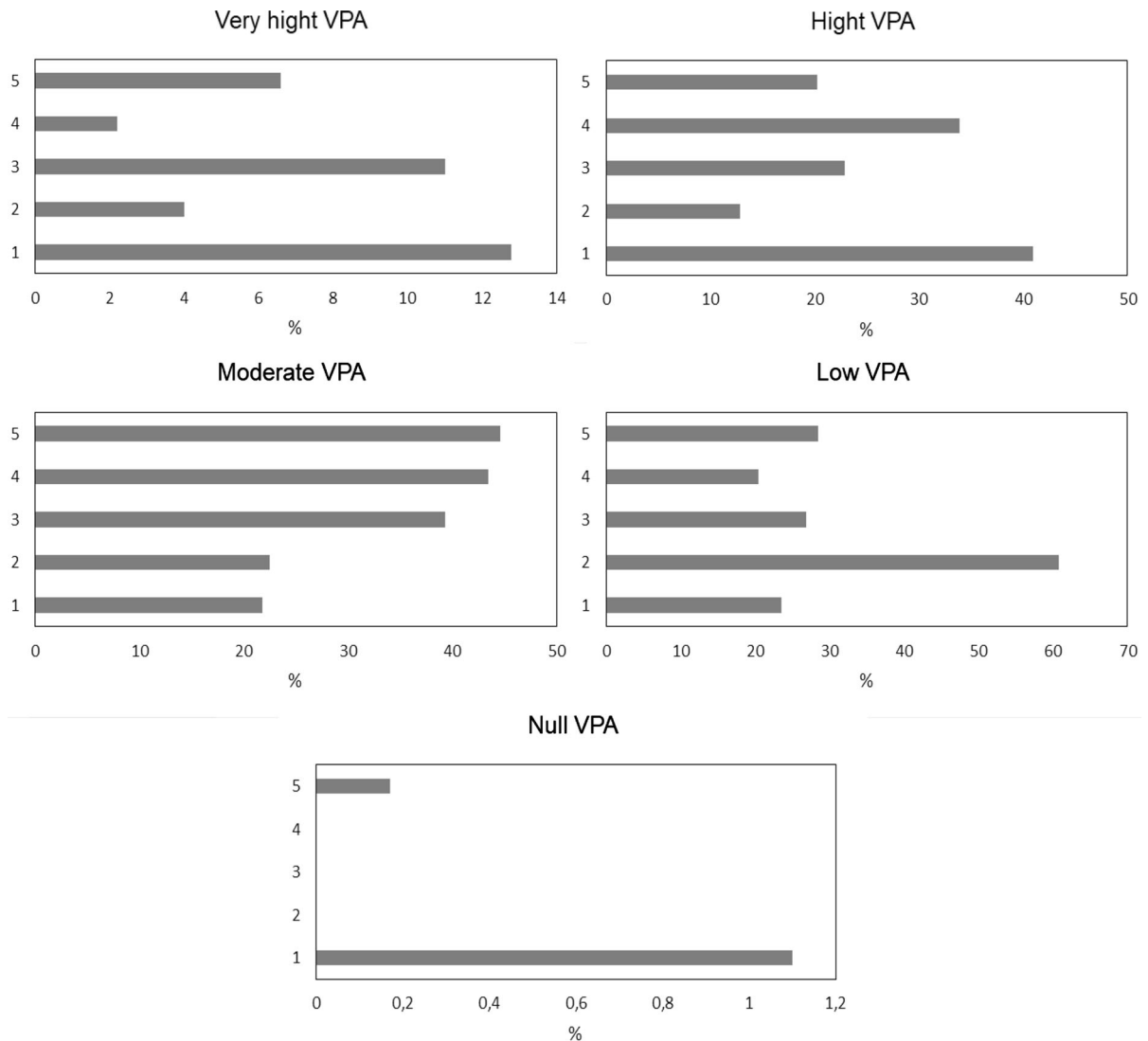


Fig. 4 Contribution of the most representative species to the potential allergenicity index

percentage, the area was selected for its typology comprising pockets-parks which are widely used for three main reasons: they are easily accessible, they invite citizens to carry out different daily-routine activities, and they offer the opportunity for the inhabitants of the city interact with nature as part of their daily life; these spaces are key in the planning and design of truly sustainable cities (Nordh, 2013; Peschardt et al., 2016).

As the results show, three of the five parks studied exceed the threshold to be considered potentially allergenic, while Alfredo Kraus and Berlín registered a very high value of allergenicity (greater than 0.5). In general, the highest percentage of contribution to the allergenicity index is made by species with high or very high VPA, that is, with a wind-pollination strategy, a flowering period lasting more than six weeks, and pollen with very high allergenic potency.



1. Alfredo Kraus, 2. Atenas, 3. Azorín, 4. Berlín, 5. Emperatriz María de Austria

Fig. 5 Percentage of individuals with different VPA in the urban parks selected

But we have also found situations in which the species with the highest contribution to the index do not have a high VPA. Instead, the number of these species in the park is exceedingly high. Thus, in Alfredo Kraus Park, the value of the index is conditioned by the high VPA of species, such as *Platanus hispanica* and *Calocedrus decurrens*, while in Atenas and Emperatriz María de Austria the greatest contribution to the value of the index is due to the presence of species with low VPA (*Sophora japonica* and *Gleditsia triacanthos* in the first park) or moderate (*Pinus pinea* in the second) but

with a high number of specimens, which increases the area of allergenic species in relation to the total area. It should be noted that highly allergenic species with relative abundance in these parks are not always the ones that contribute the most to I_{UGZA} . Thus, in Alfredo Kraus, *Thuja plicata* Donn ex D. Don and *Cupressus sempervirens* L., both with maximum VPA and a representation of 10% of the total number of specimens, only contribute 1.71% and 0.75% to the index, respectively. In the park of Berlin, *Populus alba* var. *bolleana* (Lauche) Otto, with a representation of

13% of the total trees, contributes 3.2%, and in Azorín Park, *Cupressus arizonica* with 71 individuals out of the 694 existing, contributes 4.6%.

Regarding the floristic composition of the green spaces studied, deciduous leafy species such as *Aesculus hippocastanum*, *Platanus hispanica*, *Populus alba*, *Ulmus pumila*, etc. predominate. In addition, species of the Pinaceae families (*Pinus pinea*, *Cedrus deodara*, among others), and Cupressaceae such as *Cupressocyparis leylandii* are very well represented, all of which are perennial species with an anemophilic pollination strategy and well-adapted to urban conditions. In general, the floristic composition is similar to that of other green spaces in the center of the Iberian Peninsula (Lara et al., 2017), but differs from that of localities located in the Eurosiberian region of the country and those with a temperate bioclimate which are home to species with high water requirements of the genera *Betula*, *Fagus*, *Carpinus* and *Quercus* (Kasprzyk et al., 2019), and of those of southern and eastern parks where, due to mild temperatures, the floristic panel is expanded with species of tropical origin and less hardiness zones restrictions such as *Lagunaria* spp., *Citrus* spp., *Phoenix* spp., *Jacaranda* spp., *Tipuana* spp., etc.. (Cariñanos et al., 2016).

Some studies show the relationship between tree density and the value of the potential allergenicity index (Cariñanos et al., 2017). In this study, this relationship was evident in Alfredo Kraus, which had the highest tree density (213 trees/ha) and the highest I_{UGZA} value, as well as in Emperatriz María de Austria which had the lowest value of tree density and index value. However, Atenas, despite being the second highest in tree density, had a low allergenicity index.

There is no direct relationship between the specific richness of the parks and the I_{UGZA} , since there are parks such as Emperatriz María de Austria and Azorín that with 82 and 34 different species, respectively, have a similar I_{UGZA} . This shows that the existence of a greater number of species in a green space do not translate into an increase in the value of the index (Thompson & Thompson, 2003). In fact, low diversity can lead to a higher risk for allergy sufferers in the event that any of the mass-cultivated species has a high allergenic potential.

It should not be forgotten that both the trees in the streets surrounding urban parks, as well as the pollutants produced by traffic, can aggravate allergic processes. Recent publications consider air pollution

as a stressor that increases the expression of some allergens in pollen grains, making them more aggressive in contaminated areas compared to others in uncontaminated rural areas (Bédard et al., 2019; Sedghy et al., 2018). In terms of street trees, Madrid is one of the cities in the world with the most trees on its streets, with more than 55% of the streets being tree-lined (Borrajó et al., 2018). Thus, in Berlín Park, it is necessary to take into account the 76 trees in neighboring streets that emit allergenic pollen such as *Platanus* spp. and *Ulmus* spp., among others, and that two of these streets have heavy traffic (<https://informo.madrid.es>). Atenas Park is delimited by the Campo del Moro, which can be considered as an annexed green space; it is a historical garden built at the end of the nineteenth century that occupies an area of approximately 20 ha, has a large area covered with grass, in addition to allergenic pollen producing species such as *Platanus* spp., *Cupressus* spp. and *Aesculus hippocastanum*. Emperatriz María de Austria borders on the east with the A-42 highway which has a high level of traffic since it is one of the main access roads to the city of Madrid. To the west and south, there are alignments in which the main species correspond to *Cupressocyparis leylandii* and *Platanus hispanica*. Alfredo Kraus is delimited by streets less traveled by vehicles in which the road trees are formed by species of *Platanus* spp. and *Populus* spp. Finally, Azorín Park is delimited by two avenues with heavy traffic, *Robinia pseudoacacia*, *Sophora japonica*, and *Olea europaea* being the most frequent species in the adjoining streets. We consider that these parameters can accentuate the value of the index in the parks analyzed in the city of Madrid.

Another element that may also have an impact on the value of the index is the percentage of grass cover in the green space, where grass species such as *Lolium* spp., *Poa* spp., *Festuca* spp. or *Agrostis* spp. predominate, all characterized by presenting high pollen production due to their anemophilic pollination strategy and with a high allergenic potential, which positions them as the leading cause of pollen allergy worldwide (García-Mozo, 2017). It should be noted that in this work we have found a relationship between grass coverage and the percentage of contribution to the value of the index. Thus, the parks with greater grass coverage (Azorín and Atenas) are where the percentage of contribution to the index has been higher with 1.79 and 1.86%, respectively. Conversely,

Alfredo Kraus Park had the lowest grass coverage of the five studied and therefore the contribution to the index was the lowest (0.54%). If the management and maintenance carried out on this lawn surface is adequate (frequent mowing, cleaning of spontaneous species), its incidence would be greatly reduced. A progressive replacement with artificial elements (sand, bark, etc.) or natural elements such as meadows or bushes could also be considered. In addition, it could be replaced by water elements such as ponds, lakes, estuaries, etc.

In other green areas of Spanish cities, the potential allergenicity index has also been calculated, obtaining values below 0.1 in the parks of Los Pinos (Plasencia) and La Asomadilla (Córdoba), among others, and above 0.5 in Alamedilla Park (Salamanca), Miguel Servet Park (Huesca) and Cruz Conde Park (Córdoba) (Cariñanos et al., 2014; Velasco et al., 2020). In Germany, a study carried out in a park in the city of Eichstätt obtained an index value below 0.2 (Jochner et al., 2018), while in different parks in Rzeszów (Poland) this index oscillated between 0.1 and 0.3 (Cwik et al., 2018). A work carried out in 32 urban parks in Mediterranean cities reveals that only 4 of them exceeded the value of 0.5, therefore reaching a very high allergenicity value (Cariñanos et al., 2019). If we compare this data with our results, we can affirm that in the city of Madrid the urban parks analyzed present a high allergenic potential, with two of the five studied exceeding the value of 0.5, and one the threshold of 0.3.

The results obtained also highlight the minimization measures that could be planned to reduce the allergenic impact on the sensitive population. According to Cariñanos and Casares-Porcel (2011) some of them are: using species with low allergenic potential, in the case of dioecious species such as *Acer negundo*, *Populus* spp., *Ginkgo biloba* L. planting female specimens; using entomophilous species such as acacias (*Acacia* spp.), catalpas (*Catalpa bignonioides* Walter), or false acacia (*Robinia* spp.), increasing urban biodiversity and ensuring the moderate and controlled introduction of exotic species. In experimental studies, it has been proven that *Cupressus sempervirens* and *Cupressus arizonica* are capable of producing pollens within five years of being planted, while other Cupressaceae such as *Cupressus drupezi* A. Camus, *Cupressus atlantica* Gaussen, *Cupressus torulosa* D. Don and *Cupressocyparis*

leylandii they are done at 10 years and with lower pollen production (Pichot, 2000), so it would be advisable to plant these latter species in the event that plants of this genus are to be introduced. It is also advised to respect the minimum planting distances between trees and the minimum distances between trees and buildings, which limits the screen effect and the probability of proximity pollinosis (Wong et al., 2011). Another measure that would reduce the allergenic impact would be to inform citizens about the flowering periods of the most allergenic and abundant species, which would establish the time of year of greatest risk (<https://www.comunidad.madrid/servicios/salud/polen>).

5 Conclusions

Of the five green spaces analyzed in this work in the city of Madrid, three of them present a high risk for the population with pollinosis since the I_{UGZA} reached a very high value (Alfredo Kraus and Berlín) or high value (Azorín). In general, in the parks studied, the species that have contributed the most to the index have been *Platanus hispanica*, *Aesculus hippocastanum*, and species of the Pinaceae and Cupressaceae families, most of them emitting highly allergenic pollen.

The value obtained after applying the index generates useful information of interest to citizens, since it allows direct knowledge of the possible situations that may generate a risk to their health in their local environment so that they may adopt the necessary prevention measures.

Action measures should be proposed for the design of new parks that reduce the negative impact on allergy sufferers, such as planting less allergenic species or those with low pollen, entomophilic, or female specimens.

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