How well do trees fit the city? lessons from an urban tree survey in Córdoba, Argentina

¿Qué tan bien se ajustan los árboles a la ciudad? Respuestas a partir de un relevamiento de arbolado urbano en Córdoba, Argentina

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Summary

Background and aims: Urban tree composition is generally highly diverse and largely non-native in origin. Species selection, however, should consider not only future predicted climate and species' environmental requirements, but also the regional invasion risk assessments and the respiratory health potential of species. Here, we assessed the suitability of the most frequent urban tree species by using available online databases.

M&M: Suitability was assessed by analysing tree attributes in relation to their invasive status in the study area, the respiratory health potential of the species given by their known pollination strategy and the bioclimatic match of species with the plantation zone. We grouped species according to their nativeness as non-native, regionally native and local native. After filtering those with undesirable characteristics (i.e., invasive species and/or with anemophilous pollination strategy) we analysed three bioclimatic variables: annual temperature, annual precipitation and precipitation seasonality.

Results: Results showed that the composition of Córdoba's street trees is heavily biased towards non-native species, many of which are invasive, have an anemophilous pollination strategy and/or exhibit high bioclimatic mismatch. In addition, the strong bias in the current tree composition towards species from more humid, temperate regions is evident.

Conclusions: Our results highlight the importance of revising current policy decisions to adjust urban tree flora in the face of climate change.

Key words

Anemophilous pollination, invasive species, nativeness, policy making, urban forestry.

Resumen

Introducción y objetivos: La composición del arbolado urbano suele ser muy diversa y en gran medida de origen no nativo. Sin embargo, la selección de especies debe tener en cuenta no sólo el clima previsto en el futuro y los requisitos ambientales de las especies, sino también las evaluaciones regionales del riesgo de invasión y el potencial perjuicio para la salud respiratoria. Aquí evaluamos la idoneidad de las especies arbóreas urbanas más frecuentes utilizando bases de datos de libre acceso.

M&M: La idoneidad se evaluó analizando los atributos de los árboles en relación con su estatus invasor en la zona de estudio, el potencial perjuicio para la salud respiratoria dado por la estrategia de polinización de las especies y la correspondencia bioclimática de las especies con la zona de plantación. Agrupamos las especies según su origen como no nativas, nativas regionales y nativas locales. Tras filtrar aquellas con características indeseables (especies invasoras y/o anemófilas) analizamos tres variables bioclimáticas: temperatura anual, precipitación anual y estacionalidad de las precipitaciones.

Resultados: La composición del arbolado de Córdoba está fuertemente sesgada hacia especies no nativas, muchas de las cuales son invasoras, tienen una estrategia de polinización anemófila y/o presentan un elevado desajuste bioclimático. Además, es evidente el fuerte sesgo de la composición arbórea actual hacia especies procedentes de regiones más húmedas y templadas.

Conclusiones: Nuestros resultados ponen de manifiesto la importancia de revisar las decisiones políticas actuales para ajustar la flora arbórea urbana frente al cambio climático.

Palabras clave

Elaboración de políticas, especies invasoras, origen nativo, polinización anemófila, silvicultura urbana.

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Introduction

Trees are recognized as key elements of urbanized landscapes given the valuable ecosystem services provided by tree cover in cities around the world. Temperature regulation, runoff control, carbon sequestration, wildlife sheltering and floral reward for pollinators are a few examples of the environmental benefits provided by trees (Bates *et al.,* 2011; Roy *et al.,* 2012; Willis & Petrokofsky, 2017). They also provide important social (i.e., enhancing quality of urban life), economic (i.e., energy saving), health (i.e., reducing stress), aesthetic and cultural benefits (i.e., a sense of place and identity) (reviewed in Priego-González & Breuste, 2008; Roy *et al.,* 2012). A remarkable aspect is that urban tree composition is highly diverse and largely non-native in origin (Nagendra & Gopal, 2011; Sjöman *et al.,* 2012; Freire Moro *et al.,* 2014), mainly because of early decisions on urban forestry or due to citizen´s own choices. Nevertheless, given the potential of urban areas for biodiversity conservation, the selection of plant species for urban green infrastructure has become a widely discussed topic nowadays (reviewed by Farrell *et al.,* 2022). Tree species selection strategies are usually pulling in opposite directions, from the 'natives are best' to the 'right tree in the right place' assumptions (e.g., Fontaine & Larson, 2016; Grant, 2016; Roman *et al.* 2021) often disregarding how local the final planning decisions are. Recent evidence of the effects of plants' origin on urban ecosystem function, combined with local survey data can be used to shed light on how much current urban trees fit a given city, and to further improve urban planning.

Increasing evidence points to the multiple benefits derived from the presence of native vegetation within urbanized communities (reviewed in Berthon *et al.,* 2021 and de Carvalho *et al.,* 2022). Native vegetation has been shown to be better for climate change mitigation, nutrient cycling regulation, soil stability and native animal diversity than non-native species (Berthon *et al.,* 2021; de Carvalho *et al.*, 2022). Fostering native vegetation can even be highly synergistic as community-level insect abundance and ecological interactions can be simultaneously promoted (e.g., Fenoglio *et al.,* 2023; Calviño *et al.,* 2023). In addition, native species possess great plasticity and adaptive traits that help them cope with local environmental stresses, which are particularly important in arid and semi-arid environments (de Carvalho *et al.,* 2022) avoiding waste of water by irrigation (Roman *et al.,* 2021). This, however, does not guarantee their full adaptation to future conditions challenging tree planning in the face of the current rapid climate change (Davis & Shaw, 2001). Moreover, urban systems can trigger different responses for both native and non-native species than those registered for other ecosystems (e.g., Moser *et al.,* 2017; Smith *et al.,* 2019). While recognising this range of possibilities, the benefits of native trees stand out, and are especially important for biodiversity conservation, ecosystem integrity and for people (de Carvalho *et al.,* 2022).

Planting trees is one of the most feasible actions within cities to increase urban greenery and the optimal species selection is crucial for optimizing urban green infrastructure (Roman *et al.,* 2021) and scaling up their benefits (reviewed in Ferrini *et al.,* 2020). However, the selection of tree species is not a simple task given that it might consider and weight multiple criteria, according to concrete objectives expressed at the beginning of any design and intervention. For instance, tree species should be chosen not only depending on their planting sites but also balancing the advantages and disadvantages related to both, their expected performance and the multiple benefits they provide for the human and non-human beings in the city. Among these criteria, the climatic match between species' environmental requirements and actual or predicted climate for the city has been widely used (reviewed in Farrell *et al.,* 2022). This approach, however, has usually been applied irrespectively of the species origin (i.e., not considering species' native range) (Roloff *et al.,* 2009; Yang, 2009; Sjöman *et al.,* 2016). One drawback of this approach is that some non-native species are prone to invasion (Roman *et al.,* 2021) or even more, have become successful invaders out-side their native range. Therefore, they should be subject to special scrutiny when considering them as candidate urban trees. In addition, the allergenic potential of urban tree pollen has been little considered in the past but requires special attention since pollen allergy is one of the most widespread diseases in urban populations (reviewed by Cariñanos & Caseres, 2011). Pollen release during the pollination period affects human health, prompting an allergic response in around 30-40% of the world population (Bousquet *et al.,* 2008; Pawankar *et al.,* 2011). Databases that summarize tree data on invasive species, their allergenic potential and climatic match are needed especially in regions with so many records of tree invasions like South America (Giorgis & Tecco, 2014; Richardson *et al.*, 2014). They will also contribute to improving decision making on the identity of the tree species to be implanted in urban areas. In Argentina, most of the invasive trees were introduced for ornamental or forestry purposes (i.e., 70 recognized invasive tree species in http://www.inbiar.uns.edu.ar/), and even some native species from humid regions are becoming invasive in semi-arid areas of the country (Giorgis & Tecco, 2014). Therefore, the invasive status of urban trees should be a matter of concern, especially for policy makers.

The relentless urban sprawl adds to the extensive modifications that agriculture and livestock farming have made to the land surface over the last half-century. Under this scenario, and considering that the global growth rate of urban lands was higher than the population growth rate over the last 30 years -which is, in turn, consistently positive- (Liu *et al.,* 2020), it is imperative to consider urban green infrastructure in a functional way (Tan, 2017). Given the strong negative effect of urbanization in native plant species richness (reviewed in Hou *et al.,* 2023) and the great potential of urban habitats to contribute with native species conservation (Xing *et al.,* 2017), planning urban tree composition would benefit from nativeness. This is especially meaningful in places with a strong colonial imprint on urban forestry (i.e. prevalence of non-native plants) like America, since urban trees are part of an inherited landscape (Roman *et al.,* 2018). Therefore, recognizing the role of local socio-political history in the urban tree stock is crucial and incorporating this view into current forestry decisions is paramount if a more native future is sought. A first step in planning any intervention is to know the current species composition of a city's tree stock, which is unknown in many South American cities. As an example, in Argentinian cities, despite the large non-native forestry history and the major relevance of trees to increase native flora within urban areas, there has been little attention on them. Punctually, a few municipalities have developed preliminary assessments of their tree composition (e.g., https://www.rosario.gob.ar/inicio/arbolado-publicoand Buenos Aires: data available in https://data.buenosaires.gob.ar/dataset/arbolado-publico-lineal). Between 2017 and 2019, the city council of Córdoba developed a virtual platform to share information about a preliminary urban tree inventory, which was used here as a baseline for identifying common street tree species.

The aim of this study was to characterize and compare the suitability of the current urban tree species in relation to their nativeness status. For the purpose of this paper we decided to narrow the nativeness status into three groups (but see Lemoine & Svenning 2022 for broader definitions): non-native (i.e., species with no biogeographic history in the area), regionally natives (i.e., species with a regionally biogeographic history) and local natives (i.e., species with a local biogeographic history). Suitability was assessed by analysing tree attributes in relation to their invasive status in the study area, the respiratory health potential of the species given by their known pollination strategy and the bioclimatic match of species with the plantation zone.

Materials and methods

Study system

Córdoba city in central Argentina (31°20' S, 64°10' W, elevation 440 m a.s.l.) has a subtropical climate with dry winters (*Cwa* under the Köppen-Geiger classification system) (Peel *et al.,* 2007). Two phytogeographic provinces, Chaco and Espinal, converge on it (Luti *et al.,* 1979; Kopta, 1999; Oyarzabal et al., 2018). Córdoba has undergone an accelerated urbanization process (Grifone, 2014) characterized by a diffuse growth beyond the city edges. As a consequence, an accelerated metropolitanisation is taking place to hold the growing population (Marengo *et al.,* 2006). The city covers an area of 576 km^2 and has a population of 1,565,112 inhabitants (INDEC, 2023).

Species selection and characterization

The above-mentioned virtual platform has been developed to share information about urban trees. It includes common names, location, structural problems, phytosanitary status, and missing trees. A table with 22700 records located at the urban core was downloaded and it was used for the selection of target species. The scientific names of the target species were assigned by the authors. The available dataset was downloaded from https://gobiernoabierto.Córdoba.gob.ar/arbolado (accesed date:11/5/2018). Unfortunately, this preliminary survey was interrupted in 2018 before completing the entire sampling. Of the total number of species, we considered only those with at least 100 trees, i.e., 26 species, as indicators of the most frequent ones. The selected species were then categorized by their origin (see Table S1). The native/non-native status of each species was determined by regional and local floras after Pyšek *et al.* (2004), within a biogeographical perspective.

Then, species were categorized as invasive or non-invasive according to Giorgis & Tecco (2014). *Schinus areira* is a special case as its native status depends on the time scale used. This species is an example of an historic introduction (s*ensu* Lemoine & Svenning, 2022) from Peru in pre-colonial times (Demaio *et al.,* 2002). Here we decided to consider *S. areira* as a native tree. The respiratory health potential of the species was inferred by the pollination strategy of species (i.e., anemophilous or entomophilous). Respiratory allergy caused by allergens contained in pollen grains is called pollinosis, and is one of the most frequent allergic diseases (Alfaya Arias, 2002). Central Argentina is severely affected by seasonal pollinosis and in Córdoba in particular, about 80% of atmospheric pollen comes from urban trees (Ramon *et al.,* 2020), with a consequent negative impact on public health. Pollinosis is most frequent with pollen from anemophilous plants that pollinate by releasing and dispersing pollen into the air (Nitiu *et al.,* 2019). Thus, anemophilous species were treated here as potentially high allergenic and entomophilous as not allergenic. Given that ambophilous trees were very sporadic, and their floral characteristics are quite more consistent with biotic pollination, they were treated as entomophilous.

Species original ranges: the selection of geographical coordinates

Thirty spatial coordinates for each species were selected from available databases and floras, to obtain a representative sample of coordinates from species´ native distribution range (Supplementary material: Tables S2 and S3). We opted to use 30 coordinates per species to balance the sampling as some species barely reached this number while others far exceeded it. Geographic coordinates from the native range of each species were obtained from GBIF (https://www.gbif.org) using the *occ_search* and *filter* functions of the *rgbif* package (Chamberlain & Boettiger, 2017) from uploaded accessions' information. For simplicity in citations Catalogue ID were listed instead of DOI or URL of each specimen used (Table S3). For central Córdoba ten geographic coordinates that encompass the capital and nearby smaller cities (e.g., Carlos Paz, Alta Gracia) and their surroundings were defined. That is, the two biogeographical provinces that converge in the city were represented. Ten coordinates were used instead of thirty because the area to be sampled was considerably smaller than the species' distribution ranges. By projecting the coordinates on a map, we visually inspect that the selected ones were uniformly spread over the native range of each species.

Bioclimatic parameters

Three bioclimatic parameters were chosen: mean annual temperature, mean annual precipitation, and mean precipitation seasonality. We chose mean annual temperature given the joint effect of the 'heat island effect' and greenhouse gas emissions on urban temperature (McPherson *et al.,* 2018). It is worth mentioning that the aim of this study was not to assess urban heat island effects *per se*, but to provide an overview of a possible climate decoupling between species' original environments and planting areas. In addition, a validation test with an independent dataset of measured temperature and precipitation records across Europe found that annual mean temperature series dataset of the WorldClim shows good reliability for the period 1961-1990 (Marchi *et al.,* 2019). Regarding annual precipitation, predictions of WorldClim were less accurate but also more difficult to estimate than those of mean annual temperature (Marchi *et al.,* 2019). Nevertheless, Roloff *et al.* (2009) already used annual precipitation to evaluate species' suitability in urban areas. In addition, mean annual temperature and precipitation were widely used to explain species occurrence through environmental gradients (e.g., Cabido *et al.,* 2018; Zeballos *et al.,* 2020). Lastly, we chose precipitation seasonality because rainfalls are concentrated in summer and it has been shown that precipitation seasonality and temperature are the main climatic constraints for vegetation in Córdoba (Matteucci, 2018). Climatic variables were recognized as appropriate parameters when the study has a regional to global scale (Pearson & Dawson, 2003). Therefore, we consider these three bioclimatic variables as reliable parameters to estimate the degree of mismatch between species' native environments and the urban one.

The three bioclimatic variables of the native range of the selected species and those of central Córdoba were obtained with the *extract* function of the *raster* package (Hijmans *et al.,* 2015) (resolution = 10 minutes; 18.6 x 18.6 = 344 km^2 at the equator), that access to the WorldClim database (Fick & Hijmans, 2017). The *sp* package (Bivand *et al.,* 2013) was also used. We chose this resolution to represent in a general way the bioclimatic conditions, both of the city and of the original areas of tree species. With this resolution the general conditions of an area smaller than that of the city are represented. By combining points throughout the central part of the province we tried to represent the range of climatic conditions in and around the urban area. Although the urban climate is heterogeneous, this general measure represents the average condition to which trees would be exposed.

Statistical analysis

Bioclimatic variables for the native range of each species were contrasted with a sample of the same variables for central Córdoba using estimation plots (Ho *et al.,* 2019). Estimation plots provide a robust and elegant framework for presenting data. This non-parametric graphical method, based on bootstrap, allows to visualize effect sizes and their precision (i.e., its degree of uncertainty) on the same graph. Bootstrapping was set at five thousand times (resampling with replacement from the observations). For the analysis, species were filtered by their invasive status and pollination strategy so that only non-invasive entomophilous-pollinating species would remain. After that, species were grouped by their origin as: Non-natives, Regionally natives (i.e., natives from Argentina without natural distribution in Córdoba) and Local natives (i.e., natives from Argentina with natural distribution in Córdoba). Then, all species within each group were pooled and contrasted against Córdoba. If the confidence interval includes zero, there is insufficient evidence to argue that the variable under consideration differs between Córdoba and the compared group. Effect sizes can be graphically appreciated. In addition, all the 26 species were individually compared against Córdoba. These results are shown in Table S1. The bootstrap-coupled estimation analysis was made with the *dabest* function of the *dabestr* package (Ho *et al.,* 2019). All analyses were made in R environment 3.6.3 (R Core Team, 2020).

Results

By analysing the pollination strategy, invasive status and bioclimatic match of common urban tree species we assessed the suitability of nearly 80% of the recorded trees as a function of their origin (i.e., 13218 tree records belonging to 26 species, from which 14 are non-native, 8 are regionally natives and 4 are local natives) (see Table S1 for individual species responses). Overall, 39% of the species and 69% of the analysed trees were considered unsuitable for Córdoba, either because they were invasive and/ or because they were anemophilous (Table S1). Within the remaining species, considered as potentially suitable species, local natives showed the best bioclimatic matching, as evidenced by the three variables considered (Figs. 1; 2; 3). Overall, annual precipitation was the most uncoupled parameter, followed by seasonality and mean annual temperature (Figs. 1; 2; 3). Non-native species showed higher mismatches in precipitation seasonality (Fig. 3) while regionally native species showed higher mismatches in mean annual temperature and annual precipitation (Figs. 1; 2).

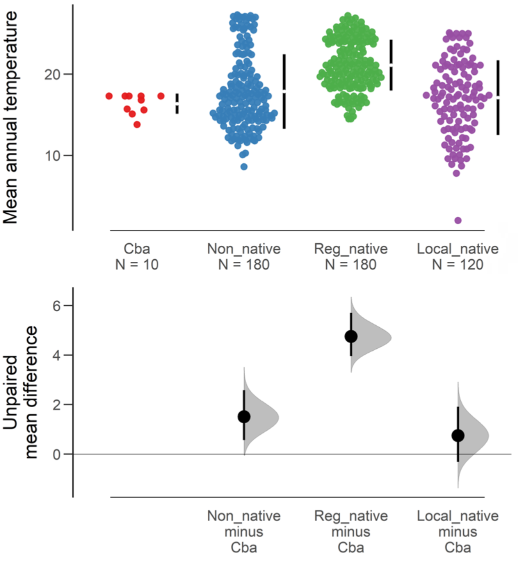

Fig. 1. Estimation plots (*sensu* Ho *et al.,* 2019) for the comparison of mean annual temperature from the native range of Non-native species (blue; 6 species), Regionally native species (i.e., species from Argentina without natural distribution in Córdoba) (green; 6 species) and Local native species (i.e., species from Argentina with natural distribution in Córdoba (purple; 4 species) against Córdoba (red). The species included in the analysis were selected according to the other two criteria: invasive status and pollination strategy (see table S1) and grouped according to their nativeness. The upper plot shows the values obtained from the WordClim database (30 values for species). The lower plot shows the effect sizes for multiple comparisons against central Córdoba (Cba), after 5000 iterations.

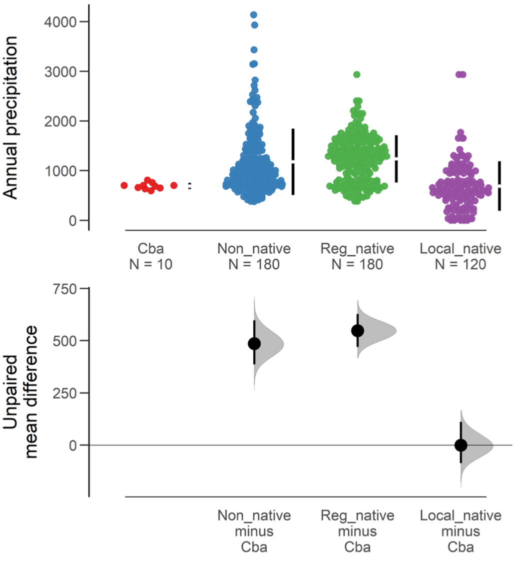

Fig. 2. Estimation plots (*sensu* Ho *et al.,* 2019) for the comparison of annual precipitation from the native range of Non-native species (blue; 6 species), Regionally native species (i.e., species from Argentina without natural distribution in Córdoba) (green; 6 species) and Local native species (i.e., species from Argentina with natural distribution in Córdoba (purple; 4 species) against Córdoba (red). The species included in the analysis were selected according to the other two criteria: invasive status and pollination strategy (see table S1) and grouped according to their nativeness. The upper plot shows the values obtained from the WordClim database (30 values for species). The lower plot shows the effect sizes for multiple comparisons against central Córdoba (Cba), after 5000 iterations.

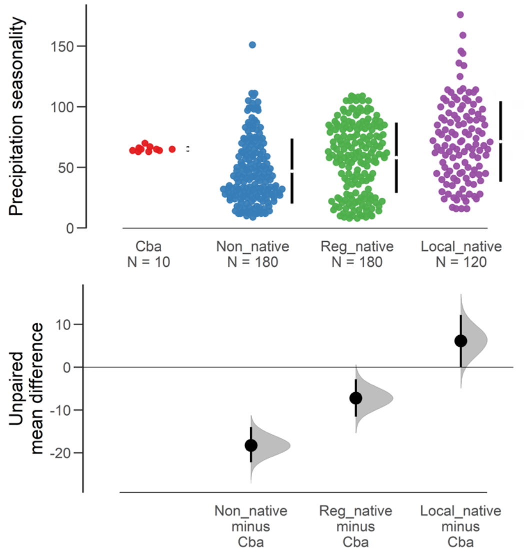

Fig. 3. Estimation plots (*sensu* Ho *et al.,* 2019) for the comparison of precipitation seasonality from the native range of Non-native species (blue; 6 species), Regionally native species (i.e., species from Argentina without natural distribution in Córdoba) (green; 6 species) and Local native species (i.e., species from Argentina with natural distribution in Córdoba (purple; 4 species) against Córdoba (red). The species included in the analysis were selected according to the other two criteria: invasive status and pollination strategy (see table S1) and grouped according to their nativeness. The upper plot shows the values obtained from the WordClim database (30 values for species). The lower plot shows the effect sizes for multiple comparisons against central Córdoba (Cba), after 5000 iterations.

Discussion

Urban ecosystems are very dynamic environments, where current management decisions may have positive effects on native species in the near future. When selecting urban trees, an appropriate mix of species that supports biodiversity and maximizes ecosystem services should be considered, not only those with easy maintenance (Nagendra & Gopal, 2010) or cultivation. Thus, an urban forestry policy that seeks functionality for people and the urban ecosystem must take into account the invasive status of species, their potential for respiratory health and/or their bioclimatic mismatch. Notably, the composition of Córdoba's street trees is heavily biased towards non-native species, many of which are invasive, have an anemophilous pollination strategy and/or exhibit high bioclimatic mismatch.

It is widely recognised that invasive trees are detrimental to biodiversity and ecosystem services, yet their use in urban environments has not ceased. For instance, *Ligustrum lucidum* is an invasive non-native species of great concern. Their wide climatic amplitude makes it abundant in different biomes around the world and its rapid adaptation to cities is facilitated by its tolerance to pollution (reviewed by Fernandez *et al.,* 2020). Special attention should be paid to the matching pattern found for this species in mean annual temperature and precipitation seasonality, since this must be related to the local success of this invader. Given that in Córdoba *L. lucidum* has spilled over from urban areas to adjacent forests in an exponential way through the last decades (Gavier-Pizarro *et al.,* 2012), it would be essential to stop their ornamental use. Another species of concern is *Bauhinia forficata* since it also shows a matching pattern and it is invading natural environments in Córdoba (Giorgis & Tecco, 2014). The environmental similarity between Córdoba and *B. forficata* native range could be facilitating its spread. Consequently, their use as urban trees should be reconsidered. Conversely, if non-native species are considered for urban tree planting, priority should be given to planting those that have some degree of climatic match but are not invasive or allergenic (e.g., *Lagerstroemia indica*). Furthermore, it would be appropriate to go further in the selection criteria for these non-native species including others such as the dispersal modes. Non-native invasive species which are dispersed by birds or wind should be avoided since these are the modes that facilitate tree invasions (reviewed by Richardson & Rejmánek, 2011).

In arid and semi-arid zones water availability is the main factor limiting natural distribution of trees (FAO, 2007). Córdoba´s urban trees natural watering and are prone to suffer higher water stress due to urban growing conditions (i.e., shallow soils and high temperatures that accelerate evapotranspiration). Precipitation seasonality may also be of great concern since the dry season is very pronounced and could further increase water stress in urban conditions, as found for three exotic urban tree species in Mendoza (Martínez 2014). Consequently, native species and those with similar bioclimatic conditions in their original ranges of distribution are likely to perform better within the city, and even more under the expected expansion of arid climate zones in the near future (IPCC 2019). Among the studied species here, only four were native from Córdoba, which shows the scarcity of native species in urban tree plantations. Overall, the native species showed a complete match pattern in bioclimatic parameters, which probably makes them suitable to live under the general climatic conditions of Córdoba. In contrast, both non-native species and those regionally native showed a completely uncoupled pattern (i.e., in all three parameters considered). The mismatch in annual precipitation and seasonality is a matter for careful consideration as water stress might promote pest outbreaks (Raupp *et al.,* 2010). For regionally native species in particular the observed decoupling is likely linked to the widespread use of ornamental plants from humid temperate regions of the country (e.g., *Handroanthus spp*.).

Native trees (i.e., here considered as local natives) are not only suitable for local environments, but also promote interactions with native animals even in Córdoba (e.g., Galfrascoli *et al.,* 2023). Encouraging their planting in cities could help to counteract the global pollination crisis and the generalized negative effects of urbanization on arthropods´ communities (Fenoglio *et al.,* 2020). Furthermore, using more native plants would help to maintain arthropods communities' integrity and in turn, the populations of animals that consume them (Burghardt & Tallamy, 2013, Liang *et al.,* 2023), promoting a higher biodiversity conservation. The implementation of native plants in cities not only depends on legal promotion, but also on their availability in local nurseries and the value that the neighbours give to these species that represent the natural heritage of the region. Consequently, it would be necessary to encourage native tree production to reach this purpose. In addition, the urban tree decision process would considerably improve by integrating the perspective of different stakeholders (e.g., citizens, plant breeders, policy makers), which is well beyond the scope of the present study.

Finally, it was recently found that urban tree cover has a direct negative effect on *Aedes aegypti* mosquito occurrence in Córdoba city (Benítez *et al.,* 2019). However, in spite of being important components of public health, urban trees in Córdoba are still insufficient in number and have poor phytosanitary conditions. Even worse, allergenic species like *F. pennsylvanica* are over-abundant (26% of the total trees recorded), which is of concern since the amount of pollen released into the air is directly proportional to the number of individuals of a single species in any given area (Cariñanos *et al.,* 2014) and considering that no single species should exceed 10% of the total number of planted trees (Dowhal 2016).

Conclusions

Most of the street trees would not fit well in the city, which is a worrying situation that demands concrete action. Córdoba tree species composition is heavily biased towards non-native species, many of which are invasive, have an anemophilous pollination strategy and/or exhibit high bioclimatic mismatch. Given the key ecosystem services that trees provide in cities and considering the fact that Córdoba is expected to expand during the following years, policy makers should answer whether and how urban green infrastructure would contribute to ameliorate climate change effects. In order to design a healthy and ecologically functional urban tree infrastructure, and to promote the connectivity of the urban landscape with the remaining native urban vegetation, an integrative approach for tree species selection is urgently needed. We hope that the results obtained from the present study will contribute with future, more healthy decisions on tree urban composition in the city of Córdoba.

Author Contributions

GG: investigation, project administration, writing-original draft, formal analysis, review and editing, visualization. GB: investigation, review and editing, resources. AC: conceptualization, methodology, review and editing, resources, supervision, project administration.

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Primary data availability

The link from which the tree records were originally downloaded is no longer available. The data set has been uploaded to Repositorio de Datos de Investigación (CONICET): https://ri.conicet.gov.ar/handle/11336/218628

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