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Assessment of the Diversity, Abundance and Range of Invasive Alien Plant Species in Córdoba, a Mediterranean Urban Area

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Abstract: Invasive species are a major driver of environmental change and pose a significPant threat to native biodiversity due to their ability to invade and establish themselves in natural or semi-natural ecosystems. This study analyzed the presence, abundance, and distribution of invasive alien plant species in a Mediterranean urban area, the municipality of Córdoba (Andalusia region, southern Spain). It includes an important historic city center, urbanized areas but also peri-urban natural and semi-natural sites around. A detailed review of bibliography and computerized botanical databases was conducted prior to an extensive fieldwork and GIS analysis carried out during 2021, 2022, and 2023. Our research identified 227 populations of 17 invasive plant species from 10 different families. These species represent 35% of the invasive plant species reported in the Andalusia region and 27% of those reported in Spain. In total, 53% of the species were introduced from America, especially South America, but no alien invasive species from other European regions were detected. The highest concentrations were found in ruderal areas, followed by abandoned fields, but also in urbanized areas, including the UNESCO World Heritage historic city center. Seven invasive herbaceous species were identified (perennial herbs), compared to 10 invasive tree species, with phanerophytes being the most abundant life form. This likely reflects the predominant use of alien woody species for ornamental and reforestation purposes, as well as the greater resilience of woody and perennial species to the increasingly warm and dry conditions of the Mediterranean climate—a phenomenon exacerbated in recent years by climate change. Our findings suggest that the use of non-native species as ornamentals is the primary driver of the establishment, spread, and ecological impact of invasive plants in the study area. This study provides valuable insights into the current situation and the potential future trajectory of invasive species, facilitating the development of management strategies and restoration efforts to address the growing issue of biological invasions in the Mediterranean region.

Keywords: plant invasive species; biological invasions; biodiversity conservation; urban invasions; Mediterranean area

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1. Introduction

Since humans began domesticating and cultivating plants, thousands of species have spread beyond their natural ranges, with many becoming effectively naturalized in both anthropogenic and natural habitats. This process has accelerated alongside advancements in communication, trade, urbanization, and the impacts of climate change [1–3]. As well as unintentionally introduced species, active introduction has often occurred, usually associated with the design of gardens, urban green spaces, and peri-urban landscapes [4]. Urban areas not only create new habitats for these species but also, in some cases, facilitate their colonization through soil degradation [5,6].

The term *invasive plant* typically refers to species that cause ecological or economic harm [7,8]. It is estimated that 50–80% of naturalized plant species have negative effects in their new environments, with about 10% causing substantial changes to the character, condition, form, or function of ecosystems [9]. Understanding which alien species are present in a given area is a critical first step in managing and conserving habitats, ecosystems, and their biological components [3].

The European Environment Agency has identified 163 invasive alien species that have posed threats to European ecosystems since 1950. Most of these species originate from North America and Asia, with some originating from other parts of Europe. In the Mediterranean region of Europe, it is common to encounter alien species from areas with similar Mediterranean climates, such as the western United States, western Chile, southern Africa, or southern Australia. Other species originating from different climates also are now adapted to the Mediterranean climate, characterized by abundant sunlight and warm temperatures, providing key meteorological conditions that are particularly favorable for plant growth [10].

Within the European Union, Regulation (EU) No. 1143/2014 of the European Parliament and the Council, adopted on 22 October 2014, provides clear guidelines on the prevention and management of the introduction and spread of invasive alien species. This regulation establishes rules to prevent, minimize, and mitigate the adverse impacts of invasive alien species on biodiversity and associated ecosystem services [11].

Spain has a remarkable plant biodiversity, with approximately 9000 species of vascular plants and an endemicity rate of about 20%. This rate is higher than that of other Mediterranean countries such as Greece (13%) and Italy (11%) and significantly greater than the average endemicity rate in Central European countries, which is around 1% [12]. Spain's rich biodiversity can be a positive factor to resist alien plant naturalization because the higher the biodiversity, the higher the ability to resist invasion by foreign plants, but the increasing temperatures and the decrease in rainfall due to climate change combined with its strategic location in the southern Mediterranean, makes it particularly vulnerable to the introduction, naturalization, and invasion of alien plant species.

According to data from the Spanish Ministry for the Ecological Transition and Demographic Challenge (METDC), in recent years, around 502 alien species, including plants, fungi, and animals, have been detected in Spain. Of these, 306 species have already become naturalized, and nearly 200 are classified as invasive alien species by the METDC [13]. Specifically, regarding plants, the 2024 *Spanish Catalogue of Invasive Alien Species*, published by the METDC, lists 64 invasive alien vascular plant species.

Andalusia, located in southern Spain, is a large region spanning 87,591 km^2 and distinguished by its remarkable plant biodiversity. The region's vegetation includes more than 25% endemic plant species, approximately 450 in total, and 20% of its surface area is protected under various environmental conservation designations. Despite these protections, more than 300 alien species—both plants and animals—have been recorded in Andalusia, introduced either intentionally or unintentionally [3]. Of these, 180 species are currently naturalized. For vascular plants, in Andalusia, there are 172 species from the Spanish List of Species under Special Protection Regime, while 49 species growing in this region are categorized under the *Spanish Catalogue of Threatened Species*, published by the METDC [13].

Notably, the list of the 100 worst invasive alien species globally proposed by the International Union for Conservation of Nature (IUCN) [14] includes two plant species with a significant presence in Andalusia: *Arundo donax* L. and *Eichhornia crassipes* (Mart.) Solms. Another highly invasive species, the "tree of heaven" (*Ailanthus altissima* [Mill.] Swingle), has become increasingly abundant in recent years, spreading across ruderal, urban, and natural areas.

To address this issue, the region of Andalusia has implemented a Program for the Control of Invasive Alien Species. This dynamic initiative consolidates various ongoing efforts and is built around three key components: prevention, action, and information. As part of this program, the present study focuses on evaluating the distribution of invasive alien plant species in Córdoba, the largest municipality in Andalusia, covering 1253 km^2.

In addition, this city boasts one of the largest and best-preserved historic city centers in Europe, designated a UNESCO World Heritage Site in 1994, which serves as its primary economic driver. Therefore, it would be particularly relevant to determine the presence of invasive plant species in this area and evaluate their potential threat to this valuable cultural heritage.

A comprehensive survey was conducted within the city and its surrounding areas to locate, inventory, and assess the presence of naturalized alien and invasive plant species. The study encompasses urban, semi-natural, and natural areas throughout the municipality. Given the municipality's extensive size, the economic and tourism significance of its surrounding natural ecosystems, and its location within Andalusia—a region both ecologically fragile and severely affected by climate change—this research is vital. It offers critical insights into how biological invasions are currently altering natural vegetation in this important part of the Mediterranean region in southern Spain [15].

The main objective of this study is to create a detailed inventory of invasive plant species in the municipality of Córdoba, documenting their distribution, abundance, and specific locations. The results aim to provide an accurate assessment of the current situation of plant alien invasive species in the study area in terms of diversity, habitats, origin, and distribution for evaluating the potential impacts on native flora and to predict possible future developments. Ultimately, the findings seek to inform the design of effective management strategies and restorative actions to mitigate the growing challenge of biological invasions.

2. Materials and Methods

2.1. Study Area

The municipality of Córdoba, located at 37°52′38″ N, 4°47′16″ W, spans an area of 1253 km^2, accounting for 10% of the province of Córdoba. It includes the city of Córdoba (576 km^2) and six surrounding towns (Figure 1). This makes it the largest district in Andalusia and the 12th largest by area among Spain's 8131 districts. As of 2023, the municipality has a total population of 324,000 inhabitants.

It is located on the banks of the Guadalquivir River, which runs from east to west, forming several meanders. To the north of the municipality lies the Sierra Morena Mountain range, while the south is dominated by vast areas of cereal fields and olive groves. The town is situated at 123 m above sea level, although the municipality's elevation ranges from 78 m near the Guadalquivir River to 692 m at the highest point in the Sierra de Córdoba. The soils in the northern region, associated with the Sierra Morena, primarily develop on metamorphic rocks and feature gentle slopes. In contrast, the southern and central areas around the Guadalquivir River are characterized by flat terrain with clay soils derived from loamy sediments.

Climatically, the area belongs to the Mediterranean region, classified as type C according to the Köppen climate system [16]. The climate in Córdoba is warm and temperate, with an average annual rainfall of 518 mm. July is the driest month, averaging 2 mm of rainfall, while November is the wettest, with 68 mm. The average annual temperature is 17.9 °C, with July being the hottest month (27.5 °C) and January the coldest (9 °C). Córdoba also enjoys significant sunshine, averaging 3390 h per year. July has the highest daily sunshine hours (12.94 on average), while January records the least, at 6.15 h [17].

The natural and semi-natural landscape of the area is typically xerothermic-Mediterranean, characterized by Mediterranean oak woodlands and 'dehesa', a human-made landscape in which the dominant woody species are perennial oaks, along with junipers, wild olives, and *Pistacia* spp., among others. The herbaceous layer is dominated by grasses and species from the *Fabaceae* and *Asteraceae* families. The banks of the Guadalquivir River are home to typical Mediterranean riparian vegetation, dominated by deciduous species such as elms, alders, ashes, hawthorns, and willows.

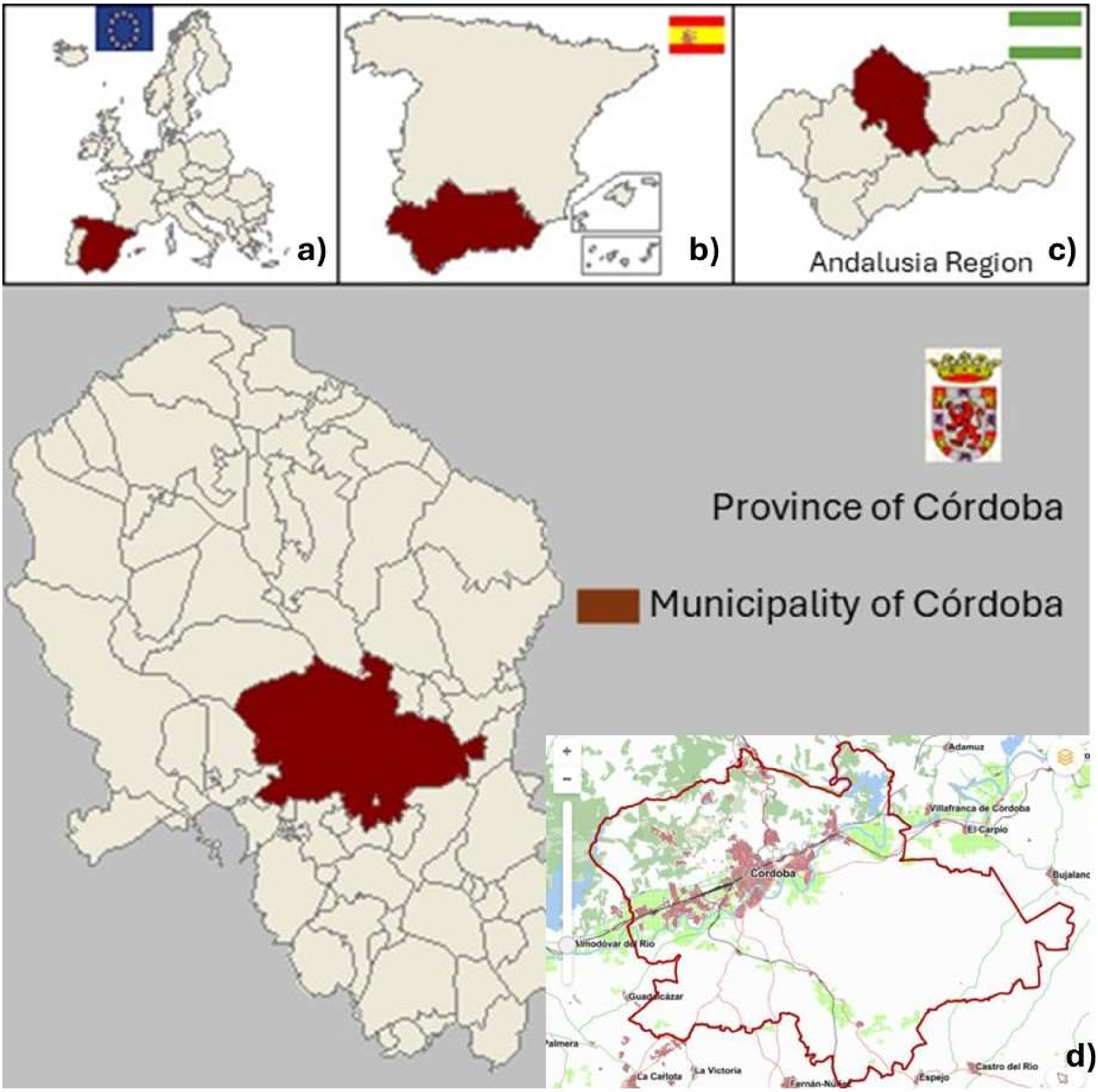

Figure 1. Location of Spain in Europe (**a**), location of the region of Andalusia in Spain (**b**), location of the region of Cordoba in Andalusia (**c**), and the area of the municipality of Cordoba in the province of Cordoba (**d**). Source: Andalusian Multiterritorial Information System (SIMA).

2.2. Data Compilation

To conduct this study, and prior to the fieldwork, a detailed bibliographic and database search was performed. Some of the books and catalogues consulted included the "Spanish Catalogue of Alien Invasive Species, the Atlas of Invasive Non-Native Plants in Spain" [12], and the book "Invasive Plant Species in Andalusia" [18,19]. These books were also used to determine the nomenclature of the alien species found in the study area, as well as their classification by status (native, alien, or invasive) and geographic origin. Additionally, information was obtained from various databases such as the Global Biodiversity Information Facility (GBIF) (https://www.gbif.org/es/, accessed on 1 April 2020) and institutions like the Department of Botany at the University of Córdoba (https://www.uco.es/botanica/es/ accessed on 1 May 2020) and the Royal Botanical Garden of Córdoba (https://www.jardinbotanicodecordoba.com/ accessed on 8 May 2020), both of which house herbarium collections. Citizen science platforms, such as the iNaturalist project "InvaPlant" (https://www.inaturalist.org/projects/invaplant accessed on 15 May 2020), were also consulted to gather occurrence data for plant species listed in the "Spanish Catalogue of Invasive Species". Data from the year 2020 backwards were reviewed to obtain prior knowledge of alien plant species already detected in Córdoba in recent years. Upon reviewing the records, it was observed that not all entries contained the necessary information; a notable example was the lack of geographical coordinates in some cases. To address this, geographical research was conducted using the available information, employing tools like Google Earth and the IBERPIX map and image viewer from the Spanish National Geographic Institute (https://www.ign.es/iberpix2/visor/ accessed on 1 June 2020).

Subsequently, a reference list of 42 potential alien invasive taxa was compiled based on the available information regarding their invasive nature in both Andalusia and Spain, and therefore, the potential presence of these taxa in Córdoba was considered. These data provided valuable insights and guidance on the potential species and locations of invasive taxa to be verified, offering support and direction for this extensive sampling effort across the entire municipal area.

2.3. Field Work

The next step was to locate in the field the sites previously identified in the research to check for the possible presence of the species. Based on prior bibliographical research and database analysis, the field sampling was planned and executed thoroughly across all the grids into which the municipality of Córdoba was divided. The entire municipality was sampled to detect the possible presence of other alien species not mentioned in the bibliography.

The municipality map was divided into a grid system of approximately 3000 m^2 using QGIS© software version 3.16. Each grid area was assigned a code to organize the fieldwork and the results obtained. Fieldwork was carried out during the years 2021, 2022, and 2023, between April and June, coinciding with the flowering season of most species. During the sampling, special attention was paid to the possible presence of the species previously described in the bibliography, to confirm or reject their presence and track the evolution of the populations. The location of each alien individual or population found in the area was recorded and digitized, including coordinates and additional data such as the number of individuals in each grid where the species was found, or the degree of ornamental use or naturalized growth, depending on where they were living (cultivated or growing and reproducing naturally in a given area).

In the field, data were recorded using a personal computer HP (manufactured at Palo Alto, CA, USA, a GPS device, eTrex Garmin 32x (Olathe, KS, USA), a, 10 × 42 Slokey binoculars device (Barcelona, Spain) and a Samsung® LP20 14-megapixel camera (Suwon, Republic of Korea), with a 27 mm wide-angle lens and x5 optical zoom, to take in situ photographs. Plant samples were carefully harvested to avoid spreading propagules across the environment and were taken to the Botany Laboratory of the University of Córdoba for taxonomic identification using various botanical atlases and alien flora identification books.

2.4. Data Analysis

Data on presence, frequency, and distribution range were analyzed, along with the area of origin and life forms, including Raunkiaer plant life forms. These data are important for invasive plant catalogues [20]. Various graphs were created to illustrate the origin, abundance, phylogeny, and other characteristics of the different alien species identified, providing a clearer understanding of the data. Finally, species distribution was presented on different maps using the QGIS© program to view, manage, edit, and analyze field data to obtain distribution maps. For this purpose, the web viewer 'Iberpix' from the Spanish

National Geographic Institute was also used to include different layers and download georeferenced maps of a given area.

3. Results

3.1. Alien Species Diversity

The fieldwork confirmed the presence of 227 populations of 17 different invasive alien plant taxa at different locations within the study area. The observed species and subspecies represent 35% of the invasive species in Andalusia and 27% in Spain. Table 1 lists the foreign plant taxa identified as invasive alien species found in the municipality of Córdoba during the study period (2021–2023). The table includes the species' names, the number of populations found, the degree of ornamental use or naturalized status, the area of origin, the plant layer (tree, herb, shrub), the Raunkiaer plant life form, and whether the species is included in the *Spanish Catalogue of Invasive Alien Species* (SCIAS). In Supplementary Material, Table S1 indicates the coordinates where the main populations were located.

Table 1. List of invasive alien species located in the municipality of Córdoba. The table includes the species name, the number of populations, the degree of ornamental use or naturalized way of life, the area of origin, the stratum (tree, herb, shrub), the Raunkiaer plant life form, and whether the alien species is included in the *Spanish Catalogue of Invasive Alien Species* (SCIAS). Abbreviations: Nº.Pop.: number of populations; % O.U.: percentage of ornamental use; % Nat: percentage of naturalization.

Species	Family	Nº.Pop.	% O.U.	% Nat	Origin	Stratum	Life Form	SCIAS
Acacia dealbata Link.	*Fabaceae*	5	100	0	Oceania	Tree	Phanerophyte	YES
Acer negundo L.	*Sapindaceae*	9	88.9	11.1	America	Tree	Phanerophyte	NO
Agave americana L.	*Asparagaceae*	19	84.2	15.8	America	Perennial herb	Phanerophyte	YES
Ailanthus altissima (Mill.) Swingle	*Simaroubaceae*	49	8.2	91.8	Asia	Tree	Phanerophyte	YES
Arundo donax L.	*Poaceae*	16	0	100	Asia	Perennial herb	Geophyte	YES
Cortaderia selloana (Schultes & Schultes Fil.)	*Poaceae*	2	50	50	America	Perennial herb	Hemicriptophyte	YES
Eucalyptus globulus Labill	*Myrtaceae*	21	15.4	84.6	Oceania	Tree	Phanerophyte	NO
Eucalyptus camaldulensis Dehnh	*Myrtaceae*	18	10.3	89.7	Oceania	Tree	Phanerophyte	NO
Gleditsia triacanthos L.	*Fabaceae*	7	71.4	28.6	America	Tree	Phanerophyte	NO
Opuntia ficus–indica (L.) Miller	*Cactaceae*	8	100	0	America	Shrub	Phanerophyte	NO
Oxalis pes-caprae L.	*Oxalidaceae*	8	0	100	Africa	Perennial herb	Geophyte	YES
Parkinsonia aculeata L.	*Fabaceae*	16	25	75	America	Shrub	Phanerophyte	NO
Ricinus communis L.	*Euphorbiaceae*	6	66.7	33.3	Africa	Shrub	Therophyte	YES
Robinia pseudoacacia L.	*Fabaceae*	23	95.6	4.4	America	Tree	Phanerophyte	NO
Sorghum halepense (L.) Pers.	*Poaceae*	15	0	100	Africa	Perennial herb	Hemicriptophyte	NO
Xanthium strumarium L. subsp. *italicum* (Moretti) D. Löve	*Asteraceae*	4	0	100	America	Annual herb	Therophyte	NO
Xanthium spinosum L.	*Asteraceae*	1	0	100	America	Annual herb	Therophyte	NO

Table 1 summarizes the most relevant features observed of the observed invasive species detected in the study area. Firstly, it is evident that the species belong to a wide variety of families, making the plant phylogeny highly diverse. The 17 identified species are distributed across 10 different families: *Asparagaceae*, *Asteraceae*, *Cactaceae*, *Euphorbiaceae*, *Fabaceae*, *Myrtaceae*, *Oxalidaceae*, *Poaceae*, *Sapindaceae*, and *Simaroubaceae*. Among these, *Fabaceae* and *Poaceae* stand out due to the higher number of species from these families (Figure 2).

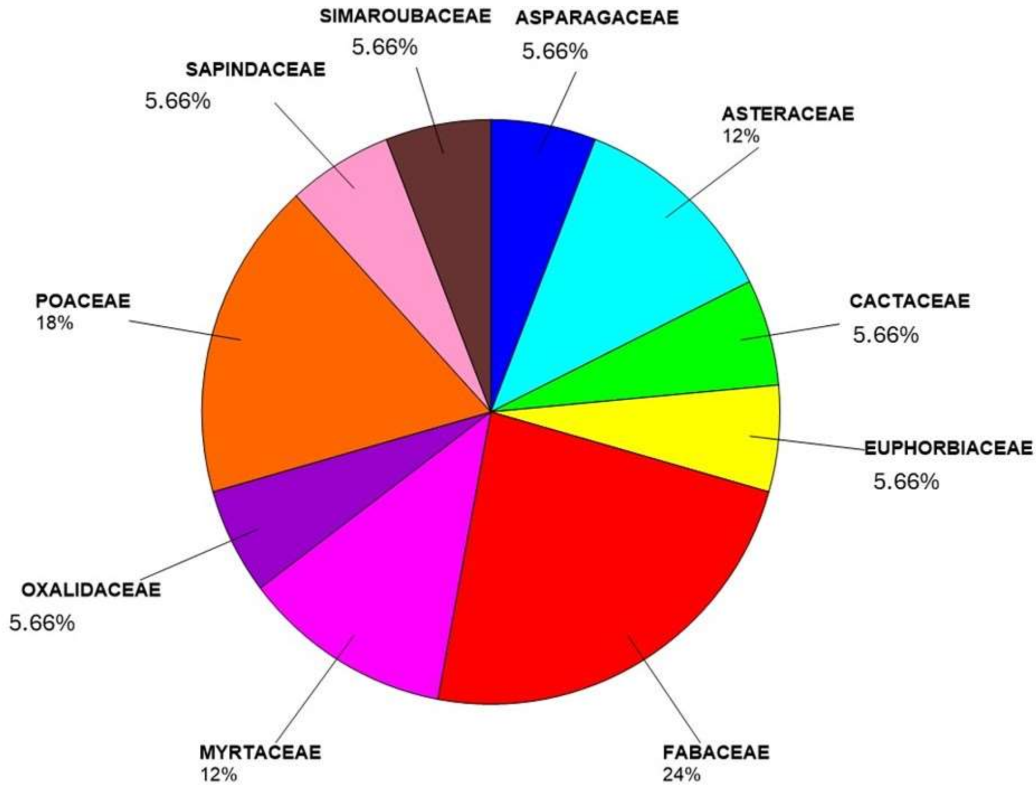

Figure 2. Percentage diagram showing the families of alien invasive plant species in the study area.

3.2. Alien Species Origins

Regarding the geographical origin of the detected alien taxa, they come from four different continents: Africa, America, Asia, and Oceania (Figure 3). Among these, America is the largest source of alien plant species in the studied area, accounting for 53% of the species found, particularly from the South American subcontinent. Notably, no alien species from other European regions were detected.

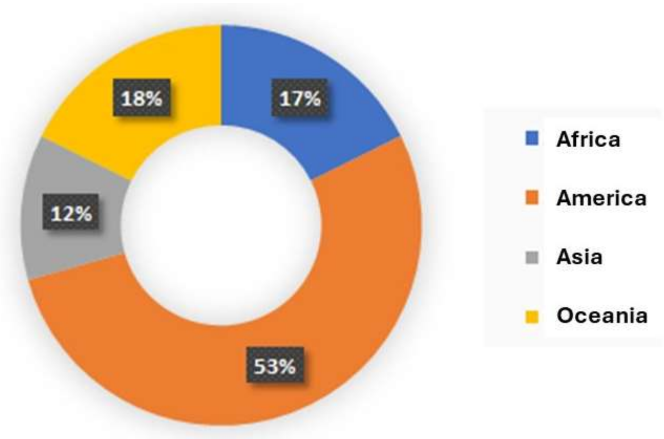

Figure 3. Percentage of invasive species recorded in the study area by origin.

3.3. Alien Species Habitats

The percentage of observed populations used solely for ornamental purposes versus those that are already naturalized and reproducing spontaneously varies across the taxa studied (Table 1). In many cases, the proportion of naturalized populations—often representing the initial stage of invasions—exceeds 75% (Figure 4). This trend is particularly notable in species with strong invasive traits, such as *Arundo donax*, *Ailanthus altissima*, *Oxalis pes-caprae*, *Xanthium strumarium*, *Xanthium spinosum*, *Sorghum halepense*, *Eucalyptus globulus*, and *Eucalyptus camaldulensis*. Conversely, the potentially invasive alien species most used as ornamental plants in the studied area are primarily trees from the *Fagaceae* family, including *Acacia dealbata*, *Robinia pseudoacacia*, and *Gleditsia triacanthos*.

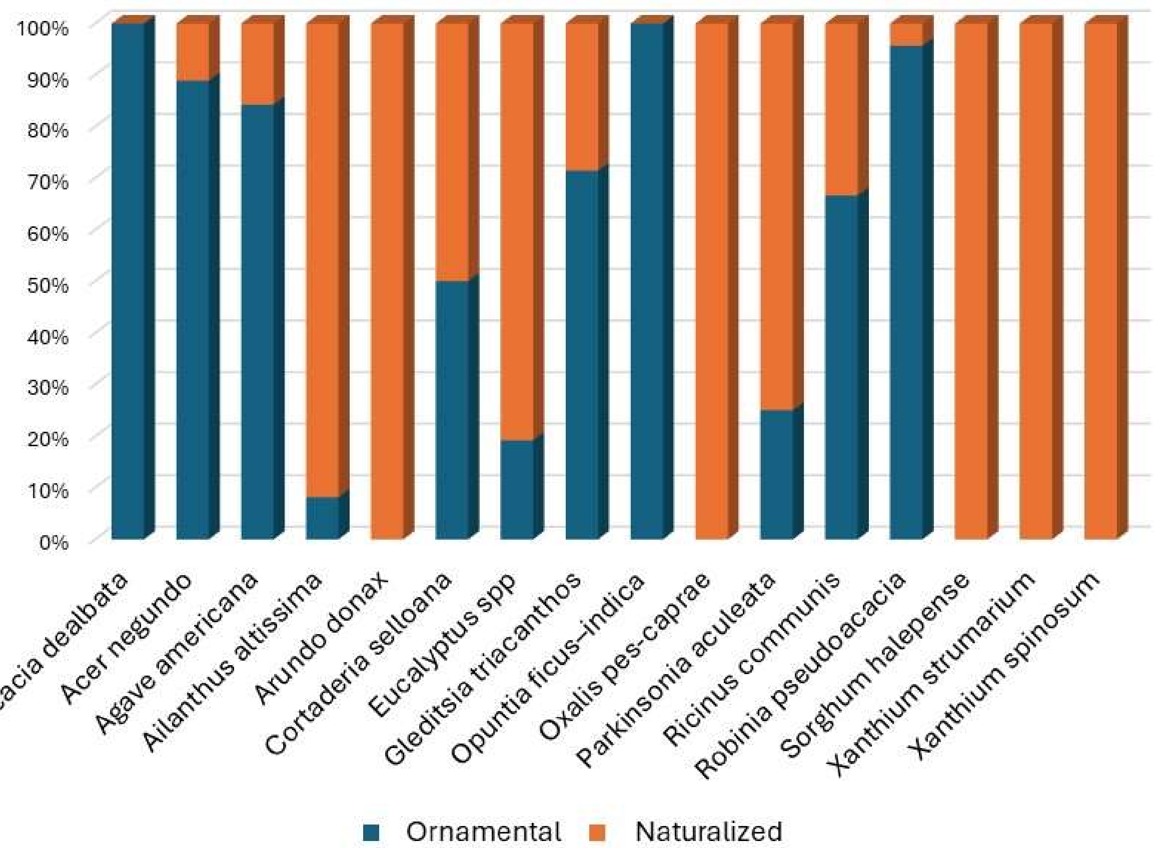

Figure 4. The percentage of plants used for ornamental purposes versus those naturalized growing spontaneously among each alien species detected in the Córdoba area.

In the case of populations of the invasive alien species in the area, an analysis was conducted based on the type of habitat in which they were observed. Four different environments were analyzed: segetal areas (weeds growing around crops), natural vegetation areas, ruderal areas, and zones with riparian vegetation (Figure 5).

The lowest proportion of species consisted of segetal ones (weeds growing around cultivated areas). These species included *Sorghum halepense*, *Xanthium strumarium*, *Xanthium spinosum*, and *Opuntia ficus-indica*, typically occupying the edges of paths and the boundaries between plots. In contrast, most spontaneously growing species were found in ruderal areas, such as abandoned soils. However, some naturalized invasive species have been observed in riparian zones of the study area, primarily along the banks of the Guadalquivir River, which traverses the city. These species include *Arundo donax*, *Ailanthus altissima*, *Ricinus communis*, *Parkinsonia aculeata*, and *Acer negundo*. Smaller populations of these species were also found near other small streams or canals within the study area. Also, the presence of some invasive species in the historic city center of Córdoba must be highlighted. In this sense, *Ailanthus altissima*, *Robinia pseudoacacia*, *Parkinsonia aculeata* and *Arundo donax* were the most frequent species observed in different parts of that area, especially in abandoned houses and gardens.

Seven out of the seventeen observed alien taxa are herbs (five perennial herbs), while the rest are trees or shrubs. Regarding their life form morphology, according to Raunkiær's classification system, four different biotypes were indetified: hemicriptophyte, geophyte, therophyte, and phanerophyte, with the latter being the most common type in the area (Figure 6).

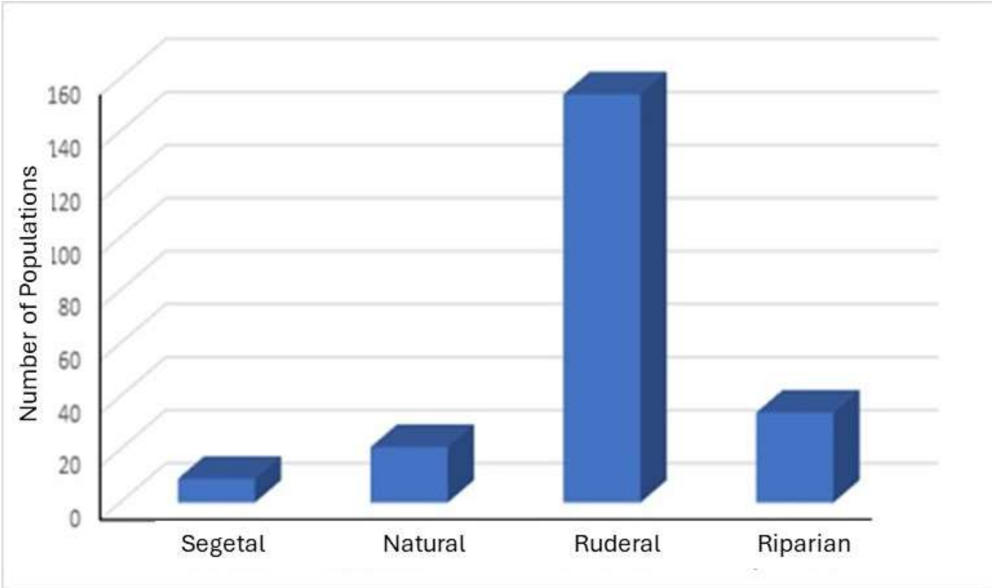

Figure 5. Distribution of alien species growing spontaneously in the study area across different environments: segetal areas, natural vegetation areas, ruderal areas, and riparian vegetation zones.

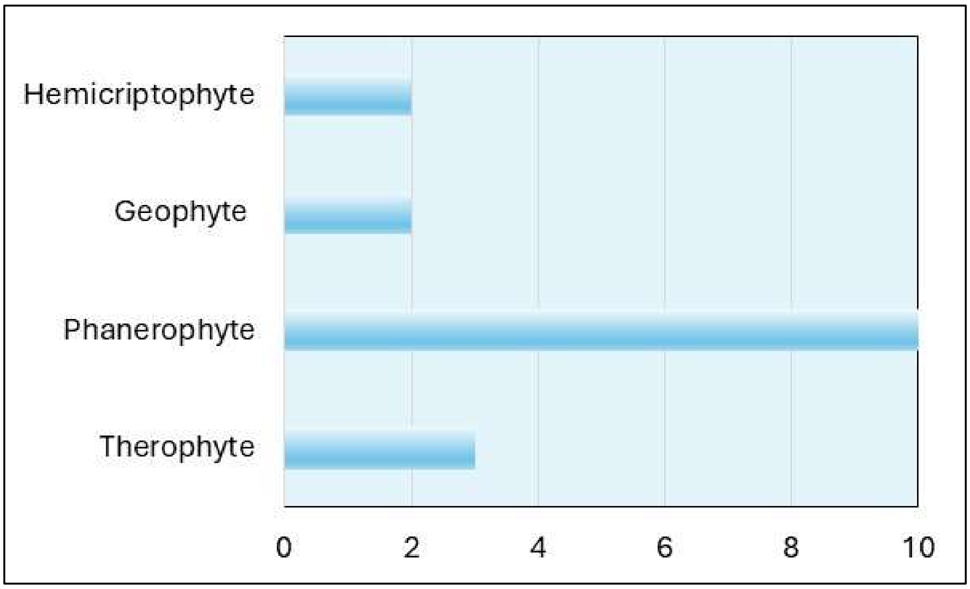

Figure 6. Diagram of the biotypes (Raunkier life forms) of the invasive plant species located in the study area.

3.4. Alien Species Distribution

In terms of species frequency and distribution, the results can be observed as distribution maps through the municipality area for all the detected alien species in the Supplementary Material (Figures S1–S13). Results reveal that the most abundant invasive species in the area is the commonly known "tree of heaven" (*Ailanthus altissima*), identified as 49 populations in 11 different locations, where it forms dense populations of mature trees (Figure S1). This species exhibits a homogeneous distribution across the municipality, being present in all types of environments. The second species in abundance is *Acer negundo*, with nine recorded populations (Figure S2). Native to North America, *Acer negundo* typically inhabits forests and riparian areas, and prefers moist substrates. In the study area, it was observed growing subspontaneously or naturalized in ditches, degraded peri-urban zones, and riparian forests.

Other abundant species include *Opuntia ficus-indica* (*Cactaceae*) (Figure S3) and *Oxalis pes-caprae* (*Oxalidaceae*) (Figure S4), each recorded in eight locations within the municipality. *Opuntia ficus-indica*, native to tropical America, was initially introduced for agricultural purposes due to its edible fruits and its use in rearing mealybugs for cochineal carmine dye production. Today, it is also valued as an ornamental plant and for creating protective hedges in arid areas due to its strong spines. In contrast, *Oxalis pes-caprae* is an herbaceous plant native to South Africa that has become widespread throughout the European Mediterranean region. In Spain, it is particularly prevalent in the south, especially along coastal areas, and extends inland through the Guadalquivir Valley (Andalusia, southern Spain). This species causes significant economic and environmental damage to gardens and crops due to its rapid asexual reproduction and the production of allelopathic chemicals that inhibit the germination of other seeds. In the study area, *Oxalis pes-caprae* forms dense ground cover, monopolizing light and space in areas with natural vegetation, thereby displacing native flora.

Within the *Fabaceae* family, four invasive species were identified in the study area: *Acacia dealbata* (Figure S5), *Gleditsia triacanthos* (Figure S5), *Robinia pseudoacacia* (Figure S6), and *Parkinsonia aculeata* (Figure S7). The frequency varies from five and seven populations, respectively, of *Acacia dealbata* and *Gleditsia triacanthos*, to 16 and 23 for *Robinia pseudoacacia* and *Parkinsonia aculeata* (Table 1). All these species, except *Acacia dealbata* (native to Australia), were introduced from the Americas for ornamental purposes. Over time, they have escaped from parks and gardens, invading forest clearings and displacing native flora. Their rapid root growth and efficient asexual reproduction make them particularly difficult to eradicate. These species now pose a serious threat to natural ecosystems, particularly in forested, peri-urban, and semi-natural areas. Specifically, *Parkinsonia aculeata* has been observed along riverbanks in the study area, where it replaces autochthonous riparian species, further disrupting the native ecosystem.

Another highly invasive species in the area is the castor plant (*Ricinus communis*), recorded in six locations (Figure S8). Its origin is difficult to determine due to its domestication and cultivation since protohistoric times. Widely naturalized in Mediterranean coastal regions, it extends into warm inland areas. In the study area, it occurs both as an ornamental plant in gardens and as a naturalized species in rough, ruderal environments.

Another notable invasive species in southern Europe present in the area is *Agave americana* (Figure S9), from the *Asparagaceae* family and native to eastern Mexico. Initially introduced as an ornamental plant for arid regions of Spain, it was later cultivated for its coarse fibers as a textile plant. Today, *Agave americana* is widespread throughout southern Spain and the Canary Islands. Beyond its decorative use, it thrives naturally along roadsides and at the edges of dry, semi-natural environments, with 19 populations observed in five locations within the study area.

Within the genus *Eucalyptus*, two species were recorded: *Eucalyptus globulus* and *Eucalyptus camaldulensis*, with 21 and 18 populations at different locations of the municipality (Figure S10). These species were observed forming extensive tree masses and colonizing a wide range of habitats, including urban, peri-urban, and natural areas.

Arundo donax (*Poaceae* family), with 16 populations (Figure S11) at different locations in the study area, is one of the highest risky alien species detected. According to the IUCN, it is one of the most dangerous and damaging invasive alien plants globally, listed among the "100 Worst Invasive Alien Species." Other highly invasive species from the *Poaceae* family observed in the study include *Cortaderia selloana* (Figure S11) and *Sorghum halepense* (Figure S12). In total, 15 populations of *Sorghum halepense* were detected, primarily in the vicinity of agricultural areas. *Cortaderia selloana*, originally introduced from Argentina for ornamental purposes, has naturalized in Córdoba and was found in two locations within the study area.

From the genus *Xanthium* (*Asteraceae* family), two species were identified: *Xanthium strumarium* and *Xanthium spinosum* (Figure S13). Both are invasive species from the Americas, introduced unintentionally to the Mediterranean region. Today, these species are widespread across most environments of the Iberian Peninsula. In Córdoba, they were primarily observed in ruderal areas, where they behave as summer weeds.

4. Discussion

Biological invasions of plant species are a natural phenomenon, but human activity and climate change have significantly accelerated this process [2]. The primary pathways of introduction include both legal and illegal trade in ornamental species, tourism, agriculture, freight transport, and human migration. These activities have increased and intensified at a much higher rate than in the previous century. Recent studies have concluded that plant invasions result from complex interactions between the behavior of alien species, the vulnerability of the receiving environment, and the history of introduction [21].

In Spain, the presence of alien invasive species is considered a significant risk and a serious threat to natural habitats [13]. The country's location in the Mediterranean biogeographical region, one of the most affected by biological invasions [22], coupled with the impact of climate change, which promotes the growth of species from warmer climates, makes Spain a "hotspot" for alien invasive species [23]. In addition to the negative ecological consequences, this situation has resulted in substantial economic losses, estimated at around EUR 232 million between 1997 and 2022 [24]. The present study examines the frequency and distribution of invasive plant species in a Mediterranean urban area and its surroundings in southern Spain as a pilot site to identify the actual situation in urban areas and surroundings in southern Mediterranean Europe, one of the most affected regions by alien plant invasions around the world [25]. Moreover, Córdoba's status as a historic tourist city makes it particularly important to understand the impact of these species on cultural heritage in urban areas, as has been observed in other European historic cities [26,27].

4.1. Alien Species Diversity and Origins

The results indicate that ornamental use has been the primary driver for the introduction of the majority of the invasive alien species observed in the studied sites. Furthermore, it was noted that most of these species have already reached the second stage, naturalization, meaning they are self-sustaining and spreading outside gardens and cultivated plots. At this stage, most naturalized species do not cause significant changes to the landscape. However, it is estimated that around 1% of these species become invasive, establishing ecological interactions with the invaded community and irreversibly displacing native flora [2]. One such example is *Ailanthus altissima*, the most frequent invasive species in the study. It is considered a high-risk invasive species worldwide, particularly in the Mediterranean region, where its presence in natural areas has sharply increased in recent years [28]. The strong allelopathic effects of its roots and seeds are comparable to those of other highly invasive tree species, such as *Eucalyptus*. Additionally, *Ailanthus altissima* poses a severe threat to the ecological balance of natural areas by sterilizing the soil through the acidity of its leaves and fruits [18].

Other invasive tree species detected include those from the *Fabaceae* family, represented by *Acacia dealbata*, *Robinia pseudoacacia*, *Parkinsonia aculeata*, and *Gleditsia triacanthos*. Their rapid root growth and efficient asexual reproduction make them particularly difficult to eradicate. Their eco-physiological characteristics pose a serious threat to natural ecosystems, particularly in forested, peri-urban, and semi-natural areas, such as riverbanks [29]. These river ecosystems hold high ecological value as corridors for native flora and reservoirs of biodiversity, making the threat of invasion in these areas highly significant and a priority for any invasion management strategy [30]. The *Fabaceae* species identified in the study area are also considered invasive in various parts of Mediterranean ecosystems due to their rapid spread in irrigated or humid environments [31]. Another invasive tree species observed near riverbanks is *Acer negundo*, native to North America. In the study area, it thrives in more humid habitats and riparian formations. This phenomenon can be attributed to its higher phenotypic plasticity, which allows it to become more invasive under favorable moisture conditions [21].

On the other hand, we identified other species adapted to dry soils, such as *Agave americana* and *Opuntia ficus-indica*, which are often found growing together in the field. In addition to being used as ornamental plants, they also occur naturally along roadsides and state borders, as observed in other parts of southern Spain and other dry Mediterranean regions [18,32]. Notably, many populations of *Opuntia ficus-indica* in the study area were infested with the phytophagous parasite *Dactylopius opuntiae* (Cockerell), commonly known as the false carmine cochineal, which plays a significant role as a biological control agent for this invasive species [33]. Similarly, *Ricinus communis* is typically found in dry areas associated with harsh ruderal environments. Originally introduced from Africa, this species is now widely naturalized along the Mediterranean coastline, penetrating warm inland regions and proving very difficult to eradicate [34,35]. Its ingestion by humans or animals can lead to severe health issues, including intestinal bleeding and organ damage, and it can be fatal within three days of prolonged exposure [36]. Traditionally, farmers affected by this plant have relied heavily on manual eradication strategies. However, scientists are now exploring other methods, such as chemical spraying and biological control [37]. Another invasive species from Africa is *Oxalis pes-caprae*, native to South Africa, which poses a significant threat to the area. It forms dense ground cover that monopolizes light and space, particularly in peri-urban and open urban areas of the study region. It is now strongly naturalized, and it causes significant economic and environmental damage to gardens and crops due to its rapid asexual reproduction and the production of allelopathic chemicals that inhibit the germination of other seeds. It greatly outcompetes native flora in the Mediterranean region. Its eradication presents a major challenge due to its rapid asexual reproduction, and no effective eradication method has been developed to date [38,39].

Within the *Poaceae* family, several species with a high invasive potential are present in the study area, including *Arundo donax*, *Sorghum halepense*, and *Cortaderia selloana*. *Arundo donax*, originally native to East Asia and introduced to Europe for use as barriers or herbaceous windbreaks, is classified by the IUCN as one of the 100 most dangerous invasive species worldwide [40,41]. In the study area, its impact on the natural environment includes the displacement of native riparian vegetation, such as *Phragmites australis* (Cav.) Trin. ex Steud. Another invasive *Poaceae* species identified are *Cortaderia selloana*, and *Sorghum halepense*. *Cortadeira selloana* was introduced from Argentine Patagonia for ornamental gardening, and nowadays, it appears naturalized in various locations within the study area, showing a strong ability to invade riverbanks, posing a significant threat to these ecologically valuable Mediterranean ecosystems [42]. In the case of *Sorghum halepense*, it was likely introduced unintentionally as an agricultural species from Africa. Today, it poses a significant invasive threat globally, particularly in Europe and North America. This issue is further exacerbated by its toxicity to livestock [43].

Within the *Asteraceae* family, *Xanthium strumarium* and *Xanthium spinosum* have been identified as two highly invasive species originating from the Americas, whose introduction to Europe was unintentional [44]. In Spain, transhumance—the seasonal movement of flocks of sheep across the peninsula in search of pasture—has played a significant role in the dispersal of their seeds. Today, these species are commonly found in almost all environments across the Iberian Peninsula. They typically thrive in ruderal areas and are also present as summer weeds in various crops [45]. In Córdoba, a few populations of these species have been recorded. However, their rapid reproductive capacity poses a potential risk to semi-natural and cultivated areas [23].

On the other hand, it should be noted that during the bibliographic research, references were found regarding the presence of other alien species in the municipality; however, these were not observed during our fieldwork. This is the case for *Fallopia baldschuanica* (Regel) J. Holub (*Polygonaceae* family) and *Pennisetum setaceum* (Forssk.) Chiov (*Poaceae*).

These species had been previously reported by other authors as forming small, naturalized populations along riverbanks, but they were no longer present, likely due to eradication efforts carried out by the Council's Environmental Department during clean-up operations [46]. Another example is *Ipomoea indica* (Burm.) Merr. (*Convolvulaceae*), cited by López-Tirado [47] as being present on the slopes of the Sierra Morena, near the municipal boundary. However, this species also appears to have disappeared from the study area. Finally, *Datura stramonium* L. (*Solanaceae*), recorded in the GBIF database as being present a few years ago, was not found during our survey. This absence is likely due to its eradication by the Council's Environmental Department, given its high toxicity and associated risks to human health.

4.2. Alien Species Habitats and Distribution

The invasive species detected in this study, apart from being found in gardens and private properties within the city for ornamental purposes, are mostly growing spontaneously in semi-natural and natural areas of the peri-urban environment. As expected, the highest proportion of alien invasive plants growing spontaneously were observed in disturbed habitats with intermittent increases in nutrient availability. In general, most of these species appear in ruderal areas, such as abandoned soils, where invasive plants with high seed germination rates, allelopathic strategies, or rapid asexual reproduction tend to dominate. However, some populations were also found in natural or semi-natural landscapes, with a consequent negative impact on biodiversity and ecosystem balance. Nevertheless, it must be pointed out that the presence of some invasive species, especially trees, in the Córdoba historic city center—a UNESCO World Heritage Site declared in 1994—poses a significant concern. Species such as *Ailanthus altissima*, *Robinia pseudoacacia*, *Parkinsonia aculeata*, and *Arundo donax* are found in abandoned houses and brownfield sites in the area, often near historical buildings and monuments. These invasive species represent a real threat, as they can harm the structures through chemical and physical damage caused by allelopathic processes or root growth.

On the other hand, it is noteworthy that 7 out of the 17 observed species are herbaceous species, with 5 of them being perennial herbs, while the rest are trees or shrubs. This overrepresentation of trees could be attributed to the widespread use of certain species in large-scale ornamental plantings (e.g., *Ailanthus altissima*) and reforestation efforts (e.g., *Eucalyptus camaldulensis*). Another contributing factor to the major presence of perennial herbs and woody species may be the area's extreme climate, characterized by prolonged dry summers, which poses challenges for the survival and reproduction of herbaceous plants from wetter climates.

The role of climate change in the region and its influence on the presence of alien invasive species is also worth considering. This likely explains why we found a greater number of invasive species populations and locations than those previously reported in the literature and databases consulted. The Córdoba area has experienced the effects of climate change in recent years, with particularly high temperatures and a significant reduction in rainfall [48,49]. These conditions could favor the spread and establishment of invasive species across all the habitats studied, including natural ones, and contribute to the displacement of native flora—a phenomenon increasingly observed not only in the Mediterranean region [22] but also in other climatic zones worldwide [50].

Moreover, land use plays a significant role in the spread of invasive species and the naturalization of ornamental species. For example, invasive plants often take advantage of abandoned agricultural land or degraded soil resulting from road construction or building projects, where they germinate and disperse their seeds effectively. The lowest proportion of species observed were weeds in cultivated areas, which aligns with the fact that the study focused on urban and peri-urban environments, where the area devoted to crops is relatively small. Nevertheless, most of the species growing spontaneously in the area were found in ruderal zones, such as abandoned soils. These areas are often invaded by species with high seed germination rates, allelopathic strategies, or rapid asexual reproduction.

This behavior is characteristic of alien invasive plant species and represents the initial stage of their introduction before spreading into natural or riparian environments [51].

Regarding life forms, Marini et al. [20] observed that the relationship between species richness and environmental factors for native species was strongly influenced by their life form, whereas alien species exhibited distinct trends that differed from the general pattern of the area. This phenomenon is also evident in our study area, where chamaephytes are the most abundant life form among native species, consistent with patterns observed across the Mediterranean region [52]. In contrast, alien invasive plants in the study area are predominantly phanerophytes, followed by therophytes and geophytes. Similar trends were observed in the relationship between species richness and human impact for both alien and native life forms across the entire urban and peri-urban area.

4.3. Contribution of Obtained Results

It is not easy for an exotic species introduced into a new environment to become invasive, as it must pass through various ecological filters. However, a certain percentage of these species manage to escape these barriers and naturalize, eventually becoming invasive. This highlights the need for greater knowledge on the management and use of alien plant species, especially for ornamental purposes. In the past, one of the main barriers was biogeographical, but this has largely been overcome through transport, voluntary introductions, and other human activities. Today, the primary challenge for these species is biological adaptation, along with the rates of admixture determined by their own biological characteristics and the conditions of the receiving ecosystem [4,9,20].

To combat invasive plants, the region of Andalusia is developing a Program for the Control of Invasive Alien Species, a dynamic initiative that encompasses various actions aimed at managing these species. The program is based on three key elements: prevention, action, and information. The results of this study contribute to the understanding of the distribution of invasive alien plant species in the largest municipality in Andalusia. Furthermore, our data can help outline the current scenario for similar cities in the Mediterranean region. This can also serve to raise awareness about a more rational and integrative approach to using natural vegetation in urban gardening. Overall, our findings provide insights not only into the current situation but also into the potential future evolution of invasive species, enabling the design of effective responses and restorative actions against the growing issue of biological invasions.

To date, the ratio of theoretical to applied management actions suggests that there are more theoretical studies than practical research or management efforts for invasive species [53,54]. For this reason, increased efforts are needed to effectively disseminate protocols and the results of real-world experiences in invasive alien species management, in order to improve practical knowledge, including that of public institutions and environmental agencies.

5. Conclusions

Our study revealed that alien and invasive plant species threaten native biodiversity in the Córdoba urban area. The results indicate the presence of 17 species officially cataloged as invasive, representing 35% of the invasive plant species in the Andalusian region and 27% of those detected across Spain. These species belong to 10 different families, with the *Fabaceae* and *Poaceae* families being particularly prominent. Species with very high invasion risks, such as *Arundo donax* and *Ailanthus altissima*, were observed in the study area.

The highest number of invasive species was primarily found in ruderal areas, followed by abandoned fields, including sites within the highly valuable UNESCO World Heritage historic city center. Phanerophytes were the most abundant life form. In terms of geographical origin, most of the observed invasive species in the area came from the American continent. Most of the observed invasive species were initially introduced as ornamental plants, subsequently escaping from public gardens or residential areas. These species have since formed invasive populations, posing substantial threats to native biodiversity and ecosystem services.

Data suggest that the urban presence of ornamental non-native species may facilitate the establishment, spread, and ecological impact of invaders in natural or seminatural areas, potentially enhancing their success under future global change conditions. This study provides important information for monitoring biological invasions and decision-making regarding the allocation of management efforts on invasive plant regards. The results indicate that the detected invasive populations in the area require urgent management intervention. We highlight our findings as a valuable knowledge base for developing effective management strategies in the area and addressing data gaps concerning the regional distribution of alien species in the Mediterranean. These efforts will be essential for safeguarding the integrity of Mediterranean urban areas and mitigating the threats from invasive species to natural vegetation areas, which is crucial for effective biodiversity conservation.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/d16120777/s1, Table S1: Location of the invasive alien plant species located in the municipality of Córdoba and Figures S1–S13: Alien plant species distribution in Córdoba municipality.

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