

Article

Ruderal Plant Diversity as a Driver for Urban Green Space Sustainability

Daniela Mogîldea  and Claudia Biță-Nicolae * 

Department of Taxonomy, Ecology and Nature Conservation, Institute of Biology Bucharest, Romanian Academy, 296 Splaiul Independentei, P.O. Box 56-53, 060031 Bucharest, Romania; daniela.sincu@ibiol.ro

* Correspondence: claudia.bit@ibiol.ro

Abstract: Urban development in south-eastern Europe has significant ecological consequences, such as a reduction in native plant diversity, the introduction of non-native species, and increased maintenance costs of urban green spaces. Achieving sustainable urban development requires a thorough understanding of the inventory of native plant species to better manage and conserve these areas. This study analyzed 806 vegetation surveys conducted in rural and urban areas over a 30-year period, identifying 450 plant species from 39 distinct plant communities. Our findings revealed generally low dominance index values in all communities, while Shannon diversity index values were particularly high, indicating rich species diversity despite urbanization pressures. Equality index values varied slightly, reflecting differences in species distributions. Principal component analysis (PCA) identified a substantial group of species with low abundance, which is essential for understanding and managing urban biodiversity. These findings have significant implications for urban planning and plant species conservation. Low dominance and high diversity suggest opportunities to improve urban green spaces by integrating diverse native species. In addition, the ecological and practical value of ruderal species, plants that thrive in disturbed environments, was emphasized, as well as their potential in medicine, phytoremediation, green roof design, and pollination services. Through directly correlating biodiversity indices with urban sustainability goals, our study provides useful insights for urban biodiversity management and the strategic integration of native plant species into urban landscapes.

Keywords: ruderal species; urban vegetation; value of ruderal species; *Galio-Urticetea*; urban biodiversity; phytoremediation; green roof design; pollination



Citation: Mogîldea, D.; Biță-Nicolae, C. Ruderal Plant Diversity as a Driver for Urban Green Space Sustainability.

Urban Sci. **2024**, *8*, 159. <https://doi.org/10.3390/urbansci8040159>

Received: 12 June 2024

Revised: 19 September 2024

Accepted: 26 September 2024

Published: 29 September 2024



Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Ruderal vegetation growing in an urban environment reacts dynamically with various elements [1], such as human activities, infrastructure, and other vegetation [1,2]. While urban vegetation covers a wide range, from street trees to herbaceous species in community gardens, ruderal vegetation often remains neglected in planned urban green spaces, despite its significant role in urban ecosystems [3]. These pioneer plants colonize disturbed or neglected urban sites and have important contributions to ecosystem functions (Figure 1) such as soil stabilization or nutrient cycling [4]. Furthermore, they act as natural air purifiers, absorbing pollutants such as carbon dioxide and releasing oxygen through photosynthesis [2,4]. Studies have shown that species like *Taraxacum officinale* (dandelion) contribute to soil stabilization by extensive root systems substantially [5]. In addition, some ruderal plants, such as *Achillea millefolium* (yarrow), are known to improve soil nutrient content by their ability to fix nitrogen, thus enriching the soil [6].

In addition, ruderal vegetation performs as a natural buffer, providing shade and evaporative cooling, thus reducing the energy consumption needed to cool buildings and increasing urban comfort [1,2]. *Betula pendula* (silver birch) has been documented to absorb substantial amounts of carbon dioxide [7], helping to reduce urban air pollution.

Ruderal species also have a significant role in managing stormwater runoff, mitigating flood risks, and protecting water quality by absorbing and filtering rainwater [2,3]. As well as providing habitat and food for urban wildlife, the ruderal species enrich urban biodiversity and strengthen ecological resilience [1,3]. For example, the deep root systems of species like *Phalaris arundinacea* (reed canary grass) enhance water infiltration and reduce surface runoff, thereby mitigating flood risks [8]. Despite their unconventional appearance, some ruderal plants, such as *Papaver rhoeas* (common poppy), contribute to the visual charm of urban areas and provide spaces for recreation and social interaction, thus improving the overall quality of urban life [4].

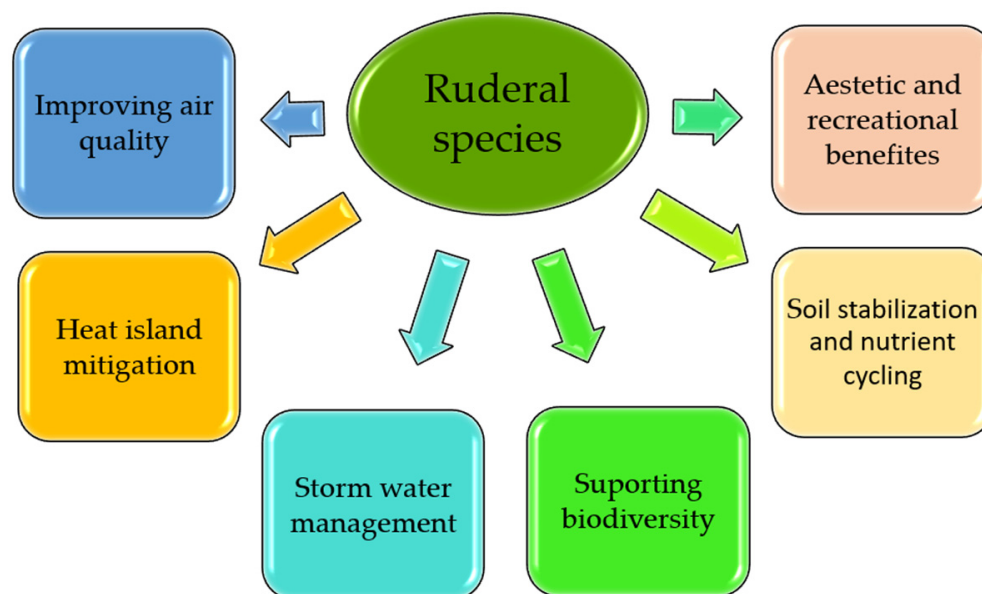


Figure 1. The main functions of ruderal plant species.

Adapted to colonize human-altered habitats, ruderal species possess traits such as rapid germination, prolific seed production, and resistance to various environmental stresses, including pollution and soil contaminants, that are common in urban areas [6]. While some ruderal species may outcompete native vegetation where it exists [9], they may also fill ecological niches left vacant by human activities and disturbances [10]. Therefore, the impact of ruderal vegetation on native biodiversity in urban environments may vary depending on local conditions and the specific context of the study area [3]. Species like *Poa annua* (annual bluegrass) can germinate and establish within a few days [11], taking advantage of temporary openings in the urban landscape before other plants are able to compete. Monitoring programs help track changes in urban plant communities over time and inform management decisions aimed at promoting urban biodiversity and resilience [9,10]. Long-term monitoring in New York City has shown how ruderal species contribute to urban green space dynamics and support pollinator communities [12]. In Europe, species-rich meadows, mown once or twice a year, are replacing traditional lawns [13], promoting a more diverse urban flora. Additionally, wildflower mixtures are being planted in public spaces, traffic islands, pavements, and rooftops, creating habitats for various pollinators [14,15].

In the context of Romania, the findings from previous studies provide valuable comparative insights. Romania's urban areas, characterized by a mix of historical urban layouts and modern developments, present unique challenges and opportunities in managing urban vegetation. For instance, the resilience observed in post-industrial landscapes in the Czech Republic [16] is relevant to Romania's post-industrial cities, where similar approaches to managing ruderal vegetation could be beneficial. The findings from India [17] and Shanghai [18] highlight the importance of understanding species composition and

distribution along the urban-rural gradient, which could inform strategies for enhancing biodiversity in Romania's rapidly urbanizing regions. Japan's focus on management regimes provides examples for Romania, where traditional and modern land management practices intersect [19]. Adapted management practices could enhance biodiversity and ecological resilience in urban areas in Romania. The Turkish study [20] on disturbance levels is particularly relevant, as Romanian cities face varying degrees of urban disturbance, from construction activities to pollution. Understanding the impact of these disturbances on vegetation can guide the development of adaptive management strategies [21].

This study provides a comprehensive analysis of ruderal vegetation, focusing on semi-natural tall grass communities within urban areas of Romania, evaluated over a 30-year period. While ruderal species are often overlooked in urban ecological studies, the research uniquely characterizes these communities from both ecological and phytocenological perspectives, offering novel insights into their roles in urban ecosystems. By integrating long-term data, the ecological dynamics of these species were evaluated as well as their potential applications in urban biodiversity enhancement and ecosystem service provision were explored.

The main objective is to characterize the communities from an ecological and phytocenological point of view. In this way, strategies for managing ruderal species in urban areas and implementing green infrastructure projects to improve urban biodiversity and ecosystem services can be developed. Moreover, the potential value of ruderal species for medicine, phytoremediation, green roof design, and their role in pollination is emphasized.

2. Materials and Methods

Romania is located in south-eastern Europe, and it has a diverse geography, climate, and soil types. It is dominated by the Carpathian Mountains with thinner and rockier soils, which support rich biodiversity, including many ruderal species that thrive in disturbed or marginal habitats. Here there are also contrasting environments where ruderal vegetation can colonize disturbed urban areas.

Romania's temperate continental climate, characterized by four distinct seasons with frequent snowfalls in the mountainous regions and hot summers in the lowland areas, contributes to the development of ruderal vegetation [22].

2.1. Area of Study and Sampling Sites

This study was generally conducted on the edge of urban and rural areas in Romania (Figure 2). The literature as well as our own data were searched. The interface between urban and rural zones in Romania presents a complex interplay of socio-economic, environmental, and infrastructural factors. Urban areas exhibit high population density, extensive infrastructure networks, and diverse economic activities. In contrast, rural regions maintain traditional practices, lower population density, and limited infrastructure. For example, survey sites within cities included areas adjacent to roads, abandoned lots, and construction sites, where disturbances such as soil compaction, pollution, and frequent human activity create ideal conditions for ruderal species to thrive. The delineation between these zones is characterized by a gradient of land use intensity, where urban sprawl gradually gives way to agricultural landscapes and small settlements [23].



Figure 2. Location of the study area (from Google Earth [24]).

2.2. Field Methods

The phytosociological surveys using the Braun–Blanquet method were conducted [25], chosen for its effectiveness in assessing plant community composition and abundance. This method was selected over others due to its well-established framework for ecological studies, allowing for detailed quantification of species presence and cover within standardized plots. Additionally, the Braun–Blanquet method is widely recognized for its robustness in capturing variations in vegetation across different habitats, making it particularly suitable for our study of diverse urban and rural interfaces in Romania. To enhance the robustness and representativeness of the data, they were adapted with the traditional Braun–Blanquet method using varying plot sizes to accommodate different communities and densities, ensuring that both sparse and dense plant communities were adequately represented. The data collected included various parameters such as locality, altitude, slope aspect, plot area, total vegetation cover, and species abundance, assessed using the Braun–Blanquet scale.

Taxonomic identification of plant species followed the standards set by World Flora Online [26]. In addition, we referred to the national literature to incorporate region-specific knowledge but also used our own expertise [27]. The research focused predominantly on the class *Galio-Urticetea* for the species [28,29]. To streamline the analysis of a substantial volume of survey data, we employed a synoptic table featuring constancy values expressed as percentages (see Table S1 List of ruderal plants). These values were coded into five distinct categories, each representing a range: Class V: 81–100%, Class IV: 61–80%, Class III: 41–60%, Class II: 21–40%, and Class I: 1–20%. This categorization facilitated the utilization of the dataset, which presented simplified frequency class values. The methodological approach allowed for a comprehensive and systematic assessment of vegetation communities, enabling robust analysis and interpretation of ecological patterns and dynamics.

2.3. Data Analysis

Data collected by the Braun–Blanquet quantitative method were subjected to statistical analysis without further transformation [25]. Species coverage in surveys was interpreted about a percentage of the total area of 100%. Subsequent analyses used species number and abundance.

The PAST 4.16c software [30] was used for statistical analysis. To analyze the ruderal species community in both classes, several indices that emphasize different aspects of community structure were utilized. The indices calculated include species richness (S), dominance (D), the Shannon index (H), equitability (J), and the Morisita similarity index. Dominance (D) Index.

The dominance index ranges from 0 to 1, where a value of 0 signifies a community where species are equally represented, and a value of 1 indicates a community dominated by a single species [30].

$$D = \sum_i \left(\frac{n_i}{n} \right)^2 \quad (1)$$

where n is the total number of individuals (in this case, the cover degree), and n_i is the number of individuals (in this case, the cover degree) of species i .

Shannon Index (H): The Shannon index, which measures entropy, considers both the number of taxa (species) and their abundance (cover degree). A Shannon index value of 0 indicates a community with a single species, whereas higher values indicate communities with many taxa, each with relatively few individuals [30].

$$H = \sum_i \frac{n_i}{n} \ln \frac{n_i}{n} \quad (2)$$

Equitability (J): Equitability, or evenness, provides insight into the uniformity of species abundances within a community [30]. It was calculated using the following formula:

$$E_H = \frac{H}{\ln S} \quad (3)$$

Morisita Similarity Index: To measure the similarity between pairs of communities, we used the Morisita similarity index. This index ranges from 0 to 1, with a value of 0 indicating no similarity and a value of 1 indicating complete similarity between communities. The Morisita similarity index assesses the degree of similarity between different species communities [30].

The diversity indices reveal the community structure of ruderal plants and the environmental factors influencing them. This analysis has important implications and helps to select suitable sites for collecting ruderal species. The main patterns of the plant communities were highlighted using the principal component analysis (PCA). The PCA analysis was carried out with normalized data. We obtained a Legendre and Legendre's correlation biplot using the "Eigenval scale" in the PAST software, which scaled the eigenvectors by $\sqrt{dk}$ and the data points by $1/\sqrt{dk}$ [30].

3. Results

There were identified a total of 450 vascular plant species in 806 plots. These represent our own data (2010–2020), as well as data from 30 years of literature (1972–2002) [31]. The recorded species were predominantly herbaceous, constituting 97.11% of the total, with shrubs accounting for 2.22% and trees for a smaller proportion of 0.67%. To simplify the calculations, we divided the data into two groups. The surveys were analyzed and grouped into distinct communities by assessing species composition and abundance. Dominant species served as key criteria for grouping. The first group comprises 229 plots across 14 communities belonging to the order *Lamio albi-Chenopodietalia boni-henrici* Kopecky 1969, while the second group includes 577 plots distributed over 25 communities belonging to the order *Convolvuletalia sepium* Tx. ex Moor 1958.

Statistical Analysis of Studied Ruderal Communities

In the first group, the highest number of species was observed in community 4, representing 35.49% of the total number of species (Figure 3). This was followed by community 3 with 31.65% and community 11 with 26.13% of species. In contrast, communities 6 and 13 had the lowest number of species, contributing only 9.11% and 10.31%, respectively.

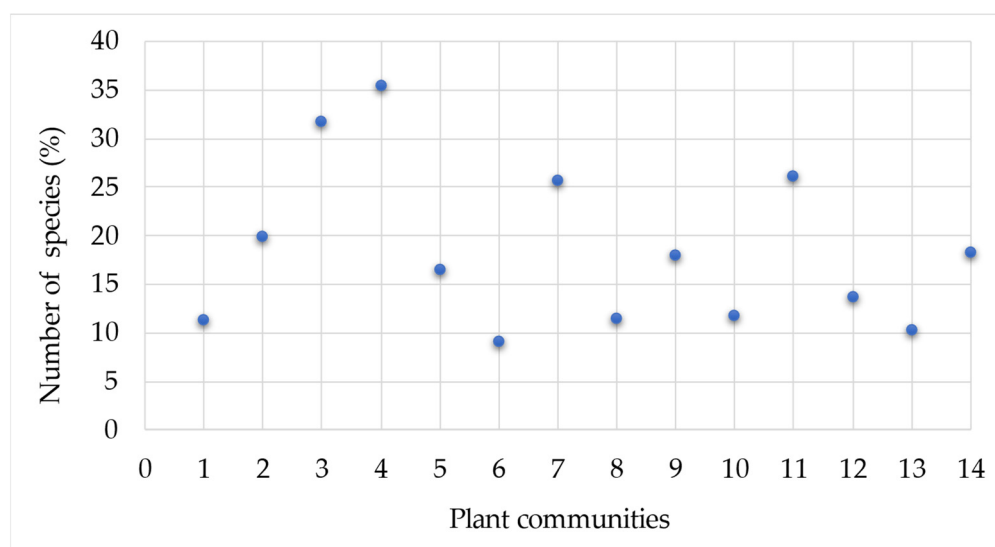


Figure 3. Percentage of species in group 1.

Dominance index values for all communities were generally low, around 0 (Table S2 diversity indices). The highest dominance scores were recorded at community 6 (0.25) and site 1 (0.17). In contrast, Shannon diversity index values were highest at communities 4 (5.18), 3 (5.10), 11 (4.88), and 7 (4.86), with community 4 showing the highest diversity of all (Table S2). Community 6 showed lower diversity compared to the others. Equitability index values ranged from approximately 1.009 to 1.069, with community 10 (1.06) and community 2 (1.01) showing slight differences in equitability (Table S2).

The dendrogram revealed distinct clustering patterns that highlight similarities and differences between communities (Figure 4). In particular, communities 14 and 6 form distinct clusters separate from the rest of the communities. In contrast, communities 3 and 4, as well as communities 7 and 11, showed greater closeness, indicating greater similarity between these pairs in the dendrogram.

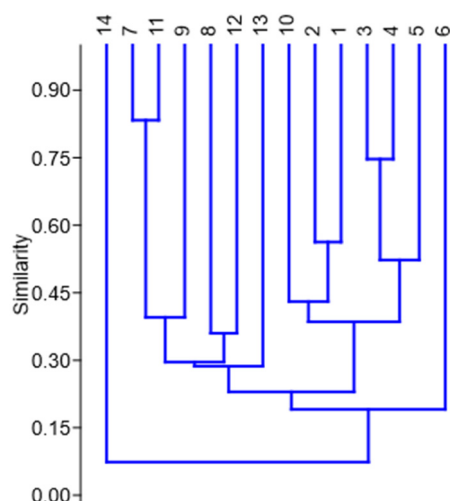


Figure 4. Similarity dendrogram of Morista index in group 1.

In the second group, community 16 had the highest number of species, accounting for 32.10% of the total, followed by community 15 with 28.63% and community 8 with 25.16% (Figure 5). In contrast, communities 5 and 3 had the lowest numbers of species, representing only 3.47% and 5.20% of the total, respectively.

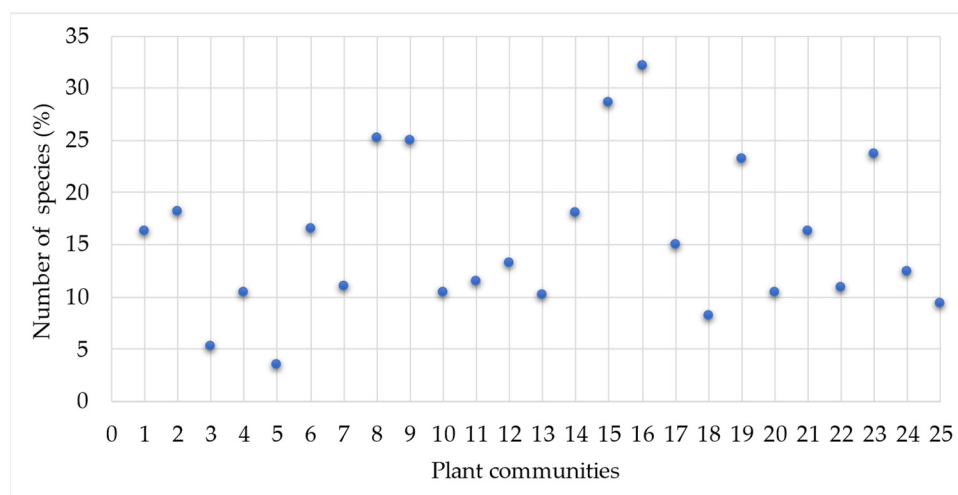


Figure 5. Percentage of species in group 2.

Several communities have low dominance index values between 0.01 and 0.02 (Table S2). In particular, a few communities, such as 8, 16, 1, 23, and 19, present even lower dominance values, between 0.003 and 0.006 (Table S3, list of medicinal species). Communities with high Shannon index values, including communities 16 (5.18), 15 (5.10), and 8 (5.07), also present Equitability_J index values between 1.008 and 1.078 (Table S3).

The Morisita similarity index revealed distinct clustering patterns among the analyzed groups (Figure 6). In the dendrogram, community 6 appeared as a distinct cluster, whereas communities 8 and 9, 15 and 16, and 19 and 23 showed notable similarities in their clustering patterns.

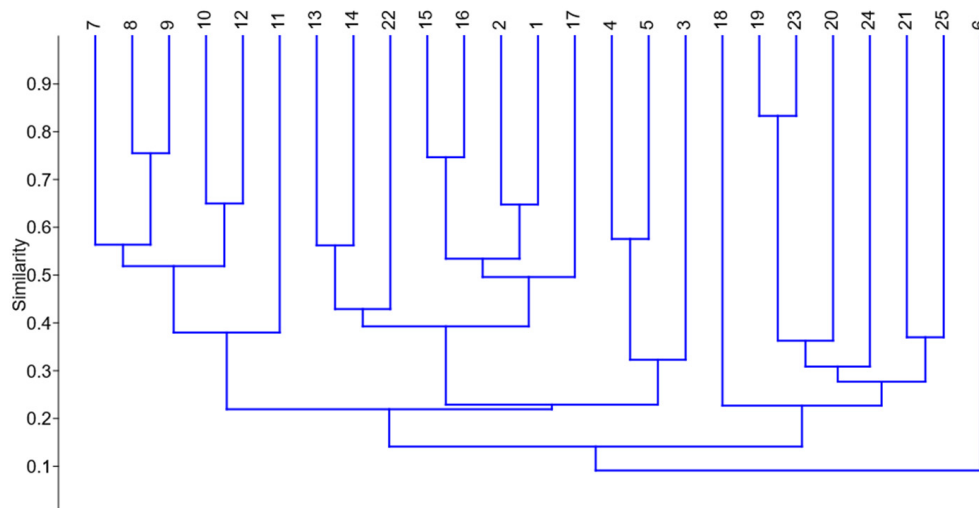


Figure 6. Similarity dendrogram of Morisita index in group 2.

PCA analysis of cumulative data from groups 1 and 2 revealed five primary components (Figure 7), with the cumulative eigenvalues of the first two components explaining 64.58% of the total variance in the original data.

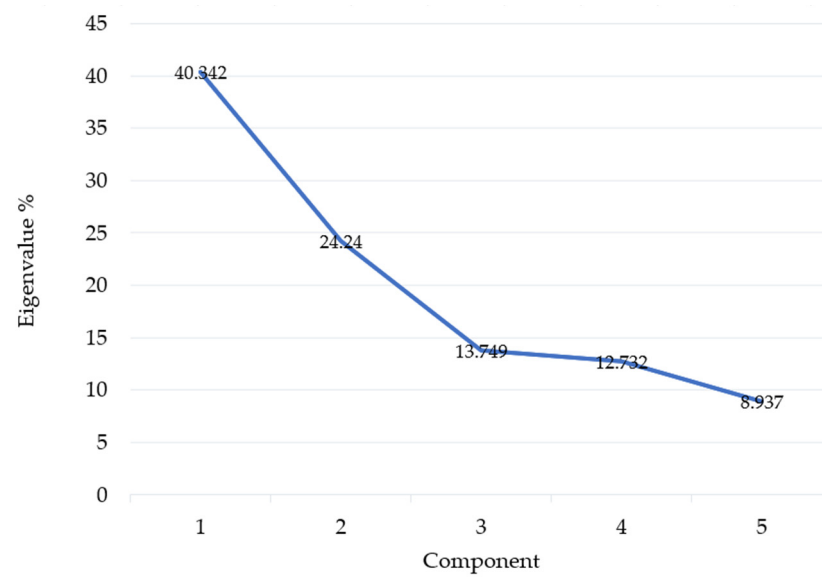


Figure 7. Percentage of eigenvalues.

In the PCA biplot (Figure 8) plant species were consistently grouped within a single cluster, as revealed by the PCA analysis.

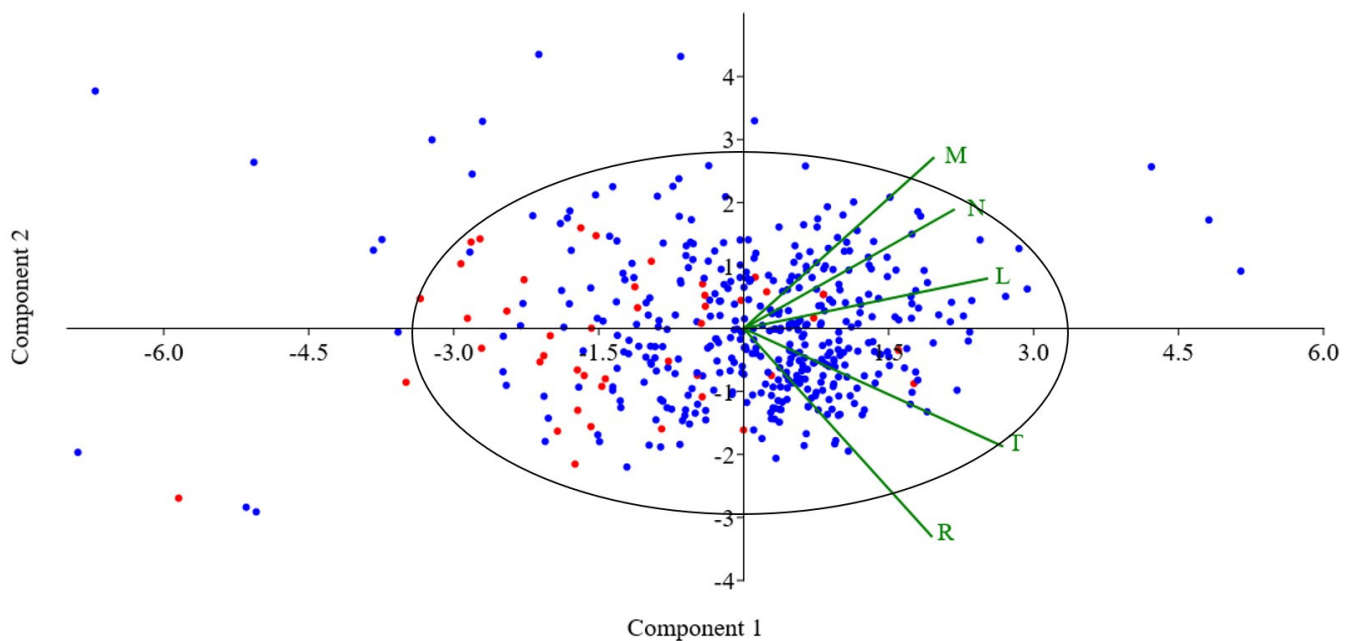


Figure 8. PCA biplot. M—soil moisture; N—soil nitrogen; R—soil reaction; L—light; and T—temperature (T). Blue dots correspond to Group 2 species and red dots to both Group 1 and Group 2.

Principal component 1 was positively influenced by soil moisture, soil nitrogen, soil reaction light, and temperature (Table 1), and principal component 2 is positively influenced by soil moisture and soil nitrogen, while soil reaction and temperature had a negative influence.

Table 1. Principal components loadings. M—soil moisture; N—soil nitrogen; R—soil reaction; L—light; and T—temperature (T).

Environment Index	Principal Component 1	Principal Component 2
M	0.38619	0.53236
N	0.42751	0.37052
R	0.38224	−0.64835
L	0.49499	0.15559
T	0.52627	−0.36709

For each species in the studied communities, the literature was reviewed to determine if they possess medicinal properties (Annex S3), contribute to phytoremediation (Table 2), are suitable for green roof design (Table 3), or play a role in pollination.

Table 2. Ruderal species used in phytoremediation.

Species	Use in Phytoremediation	Reference
<i>Achillea millefolium</i>	high Cd and Zn accumulation	Antoniadis et al., 2021 [32]
<i>Agrostis stolonifera</i> subsp. <i>stolonifera</i>	Hyperaccumulator Pb	Reeves, R. and Baker, A., 2000 [33]
<i>Arrhenatherum elatius</i>	high Cd and Zn accumulation; hyperaccumulation Pb	Antoniadis et al., 2021; Reeves, R. and Baker, A., 2000 [32,33]
<i>Artemisia vulgaris</i>	high Cd and Zn accumulation	Antoniadis et al., 2021 [32]
<i>Bromopsis inermis</i>	high Cd and Zn accumulation	Antoniadis et al., 2021 [32]
<i>Cannabis sativa</i>	Removal of environmental contamination by phytoremediation Cd, Cr, Ni, Pb, Fe	Kumar, Sanjeev et al., 2017 [34]
<i>Chaerophyllum hirsutum</i>	high Hg levels in roots	Bini et al., 2018 [35]
<i>Eupatorium cannabinum</i>	accumulated a high amount of As in its roots	González et al., 2019 [36]
<i>Galium mollugo</i>	high Cd and Zn accumulation	Antoniadis et al., 2021 [32]
<i>Lolium perenne</i>	Ni, Co, and Fe phytoextraction	Kafle et al., 2022 [37]
<i>Rumex acetosa</i>	Hyperaccumulation of Zn, Pb	Reeves, R. and Baker, A., 2000 [33]
<i>Silene vulgaris</i>	high Cd and Zn accumulation	Antoniadis et al., 2021 [32]
<i>Solanum nigrum</i>	Strong ability to accumulate Cd	Yu et al., 2015 [38]
<i>Stellaria holostea</i>	high Cd and Zn accumulation	Antoniadis et al., 2021 [33]
<i>Taraxacum</i> sect. <i>Taraxacum</i>	suitable for phytoremediation of Cd	Kano et al., 2021 [39]

Table 3. Ruderal species used in in green roof assemblages.

Species	Use for Green Roof	Reference
<i>Achillea millefolium</i>	yes	D’Arco et al., 2022; Seyedabadi et al., 2021 [40,41]
<i>Ajuga reptans</i>	cool, dry climate	Erwin and Hensley, 2019 [42]
<i>Antennaria dioica</i>	score 5 of 5 *	Hawke R., 2015 [43]
<i>Bellis perennis</i>	yes	Seyedabadi et al., 2021 [41]
<i>Calamagrostis epigejos</i>	yes	Jacobs et al., 2023 [44]
<i>Cichorium intybus</i>	yes	Walters et al., 2018 [45]
<i>Equisetum arvense</i>	yes	Jacobs et al., 2023 [44]
<i>Galium odoratum</i>	yes	Seyedabadi et al., 2021 [41]
<i>Galium verum</i>	score 4 of 5 *	Hawke R., 2015 [43]
<i>Geranium robertianum</i>	yes	Jacobs et al., 2023 [44]
<i>Leucanthemum vulgare</i>	score 3 of 5 *	Hawke R., 2015 [43]
<i>Lotus corniculatus</i>	yes	Piana and Carlisle, 2015 [46]
<i>Medicago lupulina</i>	yes	Jacobs et al., 2023 [44]
<i>Sonchus asper</i>	yes	Jacobs et al., 2023 [44]
<i>Sonchus oleraceus</i>	yes	Jacobs et al., 2023 [44]
<i>Teucrium chamaedrys</i>	yes	Jacobs et al., 2023 [44]
<i>Trifolium arvense</i>	yes	Jacobs et al., 2023 [44]

* Ratings: five is excellent, four is good, and three is fair.

4. Discussion

A total of 450 vascular plant species were identified in 806 plots belonging to 39 distinct plant communities. These recorded species were predominantly herbaceous, constituting 97.11% of the total, with shrubs accounting for 2.22% and trees for a smaller proportion of 0.67%. We noted the absence or extremely low presence of trees and shrubs. According to the literature, this indicates a simpler community structure dominated by herbaceous plants [47]. These communities are adapted to environments with regular disturbances such as grazing, mowing, or fire, which prevent woody plants from establishing. Herbaceous plants usually have faster growth rates and reproductive cycles, allowing them to colonize and dominate open areas quickly. The lack of taller vegetation increases light penetration to the ground, further favoring the growth of herbaceous species [47,48].

These communities provide habitat for a diversity of species, particularly ground-dwelling organisms and pollinators [49]. By supporting pollinators, the plants contribute to the pollination of both urban flora and adjacent agricultural crops, enhancing biodiversity and ecosystem resilience [50].

4.1. Statistical Results

High species richness and vegetation gradients from forests to ruderal communities are significantly influenced by landscape structure and human activities, highlighting the importance of suburban landscapes in biodiversity conservation [49]. In this study, the number of species observed at each of the communities was noted and agreed with the explanation provided by these authors. Diversity decreases with distance from the city center due to non-native ornamental species, highlighting the need to protect and enhance urban tree cover [51]. This explanation could also apply to the results of this study even though the hypothesis by Jha et al. [17] was not followed. Wang et al. [18] suggested urbanization impacts plant diversity, with overall plant richness, woody plants, and perennial grasses showing positive associations, while annual grasses and diversity indices show negative relationships. The low diversity values we found indicate low dominance, suggesting that no single species overwhelmingly dominates any of the communities, indicating a balanced distribution of species within communities, with some variation, but overall low dominance within communities. The Shannon diversity index had high values for some communities, indicating communities with a high number of species and lower cover, which means higher species diversity. The high Shannon index values reflect a high number of species per site, each with a low frequency, highlighting the extensive biodiversity present. Shannon index values were particularly high in some areas, indicating high species diversity. These high Shannon index values imply a rich and varied species composition at these communities, reflecting high biodiversity [49]. The values of the equitability index varied within small limits, indicating a generally equitable distribution of species across all 39 communities. This consistency implies a balanced ecological environment across all communities, with small differences influenced by site-specific conditions or other factors. In the dendrogram analysis, site 6 appeared as a distinct group, separate from the rest of the communities, indicating a unique species composition or ecological profile. In addition, communities 8 and 9, 15 and 16, and 19 and 23 showed greater proximity in the dendrogram, suggesting greater degrees of similarity in their species composition. This clustering implies common ecological characteristics or environmental conditions between these site pairs. The dendrogram based on the Morisita index provided valuable information about site grouping, revealing both isolated communities and cohesive groupings.

Principal component 1 exhibited positive associations with soil reaction, temperature, light, moisture, and soil nitrogen, and principal component 2 was positively influenced by the light, moisture, and soil nitrogen but offset by a negative contribution from soil reaction and temperature.

As previously mentioned, the plant communities studied demonstrated positive correlations with soil response and soil nitrogen. These interactions between soil development and vegetation, particularly during spontaneous succession in post-mining communities,

can change significantly over time and are interdependent. Similar results have been highlighted in other studies [16,49,52]. Temperature shows a positive correlation with the plant communities studied, with findings from other research attributing this to climate change [14]. The complex interplay between ecological dynamics and environmental changes is evident, as many alien species thrive in the warmer temperatures of cities. Light is another factor showing a similar positive correlation. Consistent with our findings, other studies suggest that early succession on nutrient-rich soils is driven by tolerance due to life-history traits and inhibition due to low light [53,54]. Additionally, temporal variability in disturbances, such as frosts, rainfall, soil disturbance, herbivore outbreaks, or drought, can promote species richness by preventing competitive exclusion. The last index, moisture, also shows a positive correlation on axis 1, with other studies validating the results [55,56]. The negative contribution of soil reaction was also observed, which is attributed to soil acidification. This aligns with findings from other researchers who confirm that soil acidification can pose a significant threat to all plant species [57]. Furthermore, there was observed the negative contribution of temperature, which can be explained by the sensitivity to low-temperature communities, as the climatic envelope they occupy is likely to disappear altogether [58].

4.2. Communities of Studied Ruderal Species

According to Mucina [28], part of the studied communities fall into the *Epilobietea angustifolii* class. These comprise the semi-natural perennial tall grass vegetation found along disturbed forest margins, nutrient-rich riparian margins, and forest clearings in temperate and boreal areas of Eurasia. The inclusion of *Galio-Urticetea* in *Epilobietea angustifolii* is a somewhat new approach, recognizing the ecological and floristic similarities between ruderal communities, whether human-influenced or natural, on nutrient-rich, moist soils. This idea, widely accepted in Central Europe [29,46], aligns with the description by Mucina in Gors et T. Muller 1969 for *Galio-Alliarietalia* Oberd. comprising ruderal and semi-natural thermophilic edge vegetation of short-lived grasses on nutrient-rich soils in submontane and montane belts of sub-Mediterranean Europe [29]. Another part belongs to the *Mulgedio-Aconitetea* class, characterized by tallgrass vegetation thriving in nutrient-rich, moist, percolating water-fertilized habitats at high elevations in Europe.

The *Lamio albi-Chenopodietalia boni-henrici* Kopecky 1969 order, referred to as *Circaeolutesianae-Stachyetalia sylvaticae* Passarge 1967, belongs to *Epilobietea angustifolii* Tx. et Preising ex von Rochow 1951, as we mentioned above [39].

Anyway, the order encompasses ruderal and semi-ruderal nitrophilous and mesophilous phytocenoses [59], representing the mesophytic ruderal vegetation [60] and semi-natural tall herb vegetation found in the mesophilous ruderal fringes and semi-natural tall herb areas on nutrient-rich and base-rich soils of temperate cold and sub-Mediterranean Europe. Characteristic species include *Aegopodium podagraria*, *Armoracia rusticana*, *Bryonia alba*, *Chelidonium majus*, *Chenopodium bonus-henricus*, *Lamium album*, *L. maculatum*, *Aristolochia clematitis*, *Geum urbanum*, *Glechoma hederacea*, *Inula helinium*, *Lapsana communis*, and *Sambucus ebulus*.

The *Convolvuletalia sepium* Tx. ex Moor 1958 order, also included in the *Epilobietea angustifolii* class, encompasses semi-natural marginal vegetation found along the banks of rivers and other water bodies in temperate Europe and the Mediterranean [61]. This group includes riverbank weeds, characterized as micro-mezotermes. Characteristic species within this order are *Calystegia sepium*, *Cuscuta europaea*, *Cucubalus baccifer*, and *Senecio fluviatilis*.

The findings of this study highlight the significant role that ruderal species play in urban ecosystems. Molina et al. [62] found that plant communities indicate ecosystem functions in urban areas, and to enhance biodiversity, carbon storage, and water regulation in Mediterranean urban green spaces, management should prevent soil compaction. To maximize their ecological benefits and to increase urban biodiversity, urban planners and biodiversity managers can adopt specific recommendations [62]: Integrate ruderal species into the design of urban green spaces: use information on species richness and functional

traits of ruderal species to select plants that are highly resistant to disturbance and to varying environmental conditions. For example, species with rapid germination [6], prolific seed production, and tolerance to pollutants [4] may be prioritized in areas prone to intense human activity or pollution.

Designing green spaces with a mix of ruderal species that can grow in different climatic conditions includes selecting drought-tolerant species for areas experiencing water deficits and flood-resistant species for regions susceptible to heavy rainfall [63]. Furthermore, the inclusion of ruderal species in bioretention basins, rain gardens, and permeable pavements improved water quality and mitigated urban flooding. Pille et Säume called for improving building-level rainwater management measures and integrating them into city-wide ecological planning to enhance urban green infrastructure and connectivity and provide multiple environmental and socio-economic benefits [64]. Using ruderal plants in areas sensitive to soil erosion, such as construction sites and urban slopes, can stabilize soil and increase nutrient cycling [4], improving soil health and supporting other plant communities.

4.3. Assessing Multifunctional Benefits of Community Species

Ruderal species are rich in a diverse range of phytochemicals with significant curative properties (Table S3). In this study, approximately 22% of the 450 plant species examined are recognized for their medicinal properties, such as *Achillea distans*; *Achillea millefolium*; *Achillea setacea*; *Aegopodium podagraria*; *Bistorta officinalis*; *Chaerophyllum hirsutum*; *Cirsium arvense*; *Linaria vulgaris*; *Taraxacum sect. Taraxacum*; *Persicaria hydropiper*; *Plantago major*; *Plantago lanceolata*; *Plantago media*; *Pastinaca sativa*; and *Origanum vulgare* [65–82].

Moreover, ruderal species can be effectively used in phytoremediation due to their ability to absorb and accumulate heavy metals and other pollutants from contaminated soils [32,39] (Table 2). Several species accumulate heavy metals such as Zn, Pb, and Cd. Some of them are considered hyperaccumulators, such as *Rumex acetosa*, *Arrhenatherum elatius*, and *Agrostis stolonifera* [33]. According to the literature, ruderal plants are good candidates for improving urban green areas and remediating polluted soils due to their adaptability and capacity to flourish in harsh environments.

The ability of ruderal species to survive high temperatures, light intensity, and low rainfall, as well as their capacity to self-replicate, makes them a suitable candidate for green roof design. Several species were already used in green roof assemblages (Table 3) [40–46], such as *Antennaria dioica*, *Galium verum*, *Calamagrostis epigejos*, *Medicago lupulina*, *Sonchus asper*, *Sonchus oleraceus*, *Teucrium chamaedrys*, *Trifolium arvense*, and *Bellis perennis*.

Furthermore, in the context of the ‘pollination crisis’ [44], maintaining plant diversity is essential for restoring environmental balance. The diversity of food sources and the amount of nectar and pollen provided by rudimentary species is significant for maintaining healthy pollinator populations [83,84]. To examine these characteristics, the researchers studied a different mix of wild flowering plants [63,85]. There are several ruderal plants that have been observed to have a high intensity of insect visits, such as *Anthyllis vulneraria*, *Ballota nigra*, *Campanula rapunculoides*, *Capsella bursa-pastoris*, *Carduus acanthoides*, *Centaurea jacea*, *Cirsium arvense*, *Cichorium intybus*, *Convolvulus arvensis*, *Daucus carota*, *Epilobium montanum*, *Galeopsis pubescens*, *Geranium pratense*, *Hypericum perforatum*, *Lamium album*, *Linaria vulgaris*, *Lotus corniculatus*, *Lychnis flos-cuculi*, *Melilotus albus*, *Melilotus officinalis*, *Oenothera biennis*, *Origanum vulgare*, *Pastinaca sativa*, *Potentilla reptans*, and *Sonchus arvensis* [84,85]. Pollinator visitation depends on the quantity and quality of floral resources (nectar and pollen). In particular, species with substantial pollen production, such as *Artemisia vulgaris*, *Ballota nigra*, *Carduus acanthoides*, *Cichorium intybus*, *Salix* sp., and *Taraxacum officinale*, are known to be excellent polleniferous, contributing substantial amounts of pollen [83]. A high diversity of ruderal species is important for restoring pollinator biodiversity. In addition, frequent occurrence and dense patches of ruderal flora contribute substantially to this process [83].

4.4. Limitations and Broader Implications

In this study, we recognize some possible limitations of the results related to the plots selected for the study that may not fully represent the diversity of urban and rural interfaces in Romania. Also, there is a possibility that more accessible or visually diverse communities may have been preferentially chosen, leading to a biased representation of ruderal vegetation. On the other hand, the surveys were conducted in certain seasons (spring and summer), which could have led to missing species that occur or are more visible at other times of the year. Since the study is based on literature surveys over a time period of 30 years, it is evident that observations were made by different observers who have various levels of expertise and perception, which led to inconsistencies in species identification and data recording. This may affect data accuracy and reliability. The heterogeneity of the urban environment implies that small-scale variations in microclimate, soil type, and human activity have the potential to influence vegetation patterns. Ignoring such heterogeneity leads to overgeneralized conclusions that cannot be applied to all urban contexts. Other studies state that the complexity of the ecosystems makes it difficult to accurately represent them in the plots, leading to variations in the measurement results [86].

Regarding the limitations of this study, we consider encouraging all observers to a constant standard and performing inter-observer reliability tests could help to reduce the errors that occur in future studies. The use of digital tools and apps for plant identification can also provide a standardized approach to data collection.

The incorporation of fine-scale environmental data and the use of spatial analysis techniques can also help account for spatial and environmental heterogeneity. Stratified sampling based on environmental gradients can provide a more nuanced understanding of urban vegetation dynamics.

Ruderal vegetation can be incorporated into urban parks, community gardens, and greenbelts, creating natural areas for recreation and relaxation. Despite their often unkempt appearance, many ruderal species have aesthetic appeal, such as wildflowers that add color and variety to urban landscapes. Creating wildflower meadows or integrating flowering ruderal plants into public spaces can improve urban aesthetics and provide a sense of natural beauty in densely built environments. In this regard, Jim [87] stated that urban green spaces that are well connected, forming a green network throughout the city, are defining characteristics of naturalistic design.

The characteristics of ruderal species are related to their ability to colonize areas affected by extreme weather events, such as floods, storms, and heat waves, and to survive in disturbed environments. Their rapid growth and resilience can help stabilize and revive urban areas after disturbance, providing immediate ecological benefits. Furthermore, these species can contribute to urban cooling by providing shade and evaporative, mitigating the urban heat island effect. This is particularly important as cities face more frequent and intense heat waves due to climate change [88].

The results of this study were compared with similar studies in different geographical or climatic contexts: In Western Europe, studies have shown a similar dominance of herbaceous species in urban ruderal communities, emphasizing their role in early successional stages and urban biodiversity. For example, research in Germany and the Netherlands [89,90] has demonstrated the ecological benefits of integrating ruderal vegetation into urban planning to enhance biodiversity and ecosystem services.

Studies in tropical cities like Singapore and São Paulo [91,92] have found that ruderal species contribute to urban resilience by rapidly colonizing disturbed areas and providing green cover, which helps mitigate the impacts of heavy rainfall and high temperatures. In cities located in arid regions, such as Phoenix (USA) [90], ruderal species are significant for stabilizing soil and reducing erosion in areas with sparse vegetation.

4.5. Conservation and Urban Biodiversity

Integrating ruderal species conservation into broader urban biodiversity strategies can provide both synergies and potential conflicts. Ruderal species can improve ecosystem

services such as pollination, nutrient cycling, and habitat provision, complementing the conservation of other urban biodiversity. Their presence can support pollinators [91], creating a more robust and resilient urban ecosystem. The use of ruderal species in green infrastructure projects, such as green roofs, walls, and rain gardens, can also enhance the ecological value of urban spaces. These projects can provide multiple benefits, including stormwater management, temperature regulation, and aesthetic improvements [92].

On the other hand, there may be conflicts between conserving ruderal species and prioritizing ornamental vegetation, especially if ruderal species outcompete or displace native plants. It is important to balance conservation of ruderal species with efforts to protect and restore native biodiversity. Implementing management practices that favor ruderal species, such as reduced mowing and minimal soil disturbance, may conflict with traditional urban design preferences. Educating stakeholders and the public about the ecological benefits of these practices can help mitigate conflicts. The findings of this study are also supported by other authors who have argued that research on the intersection between biodiversity, urban environment, and people is fundamental to developing urban policies that balance urbanization with biodiversity conservation, recognizing that cities can provide valuable opportunities to protect biodiversity across different land use types [93].

5. Conclusions

These studies highlight the dynamic interactions between plant communities, urbanization, landscape structure, and disturbance, providing valuable information for biodiversity conservation and urban planning. The study found that herbaceous plants dominate the identified vascular plant species, indicating a simpler community structure typical of disturbed environments, with implications for soil stabilization and wildlife habitat. The groups studied were characterized by ecological and floristic similarities and included ruderal communities of the orders *Lamio albi-Chenopodietalia boni-henrici* and *Convolvuletalia sepium*. The ruderal species, growing in disturbed environments, are rich in phytochemicals with medicinal properties and can be used for phytoremediation and are also known to accumulate heavy metals. They are also suitable for green roof design due to their resistance to harsh conditions. In addition, maintaining the diversity of ruderal plants is important for sustaining pollinator populations, as these plants provide essential nectar and pollen resources, helping to restore pollinator biodiversity.

Furthermore, with more and more people living in cities, it is important to protect urban wildlife. However, the study of urban ecosystems and their effects on conservation is often lacking. Specific recommendations for biodiversity conservation in urban and suburban landscapes include the implementation of policies that prioritize the conservation and creation of green spaces, such as parks, community gardens, and green roofs, which provide habitats for diverse plant and animal species. Conservation priorities should focus on protecting ornamental vegetation, promoting the use of ornamental and ruderal species in urban green infrastructure, and creating ecological corridors connecting fragmented habitats. Management practices should emphasize reduced mowing, limited pesticide use, and the development of species-rich grasslands to enhance urban biodiversity.

Policymakers should integrate ecological considerations into urban development plans, ensuring that green spaces are designed not only for aesthetic and recreational purposes but also for their ecological functions. A strong call to action urges urban planners, policymakers, and the scientific community to recognize the critical importance of urban biodiversity. Integrated approaches that consider ecological, social, and economic factors in urban development are essential for creating sustainable and resilient urban environments. By prioritizing biodiversity conservation in urban planning, the quality of life of urban dwellers can be improved, and the health and sustainability of urban ecosystems can be ensured [93].

Conservation Recommendations

We recommend developing integrated management plans that include the conservation of both ruderal and ornamental species, ensuring that the ecological functions of ruderal species are exploited while protecting native biodiversity.

We also recommend involving the public in conservation efforts by raising awareness of the ecological and social benefits of ruderal species. Community involvement can stimulate support for conservation initiatives and promote sustainable urban planning practices.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/urbansci8040159/s1>, Table S1: List of ruderal plants; Table S2: Diversity indices; Table S3: List of medicinal species.

Author Contributions: Conceptualization, C.B.-N.; methodology, C.B.-N.; and D.M.; software, D.M.; validation, C.B.-N. and D.M.; investigation, C.B.-N. and D.M.; resources, C.B.-N. and D.M.; writing—original draft preparation, C.B.-N. and D.M.; writing—review and editing, C.B.-N. and D.M.; visualization, C.B.-N. and D.M.; supervision, C.B.-N. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by project numbers RO1567-IBB01/2024 and RO1567-IBB04/2024, from the Institute of Biology Bucharest of the Romanian Academy.

Data Availability Statement: The original contributions presented in this study are included in the article; further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

References

- Knapp, S.; Kühn, I.; Mosbrugger, V.; Klotz, S. Do protected areas in urban and rural landscapes differ in species diversity? *Biodivers. Conserv.* **2008**, *17*, 1595–1612. [CrossRef]
- Prach, K.; Pyšek, P.; Bastl, M. Spontaneous vegetation succession in human-disturbed habitats: A pattern across seres. *Appl. Veg. Sci.* **2001**, *4*, 83–88. [CrossRef]
- Medvecká, J.; Jarolimek, I.; Zaliberova, M. Ruderal vegetation of the Horná Orava Region 2. Galio-Urticetea, Epilobietea angustifolii. *Thaiszia J. Bot.* **2010**, *20*, 17–52.
- Dubyna, D.V.; Dziuba, T.P.; Iemelianova, S.M.; Protopopova, V.V.; Shevera, M.V. Alien species in the pioneer and ruderal vegetation of Ukraine. *Diversity* **2022**, *14*, 1085. [CrossRef]
- Cacak-Pietrzak, G.; Dziki, D.; Gawlik-Dziki, U.; Sułek, A.; Kalisz, S.; Sujka, K. Effect of the addition of dried dandelion roots (*Taraxacum officinale* FH Wigg.) on wheat dough and bread properties. *Molecules* **2021**, *26*, 7564. [CrossRef] [PubMed]
- Radanovic, D.; Antic-Mladenovic, S.; Jakovljevic, M. Influence of some soil characteristics on heavy metal content in *Hypericum perforatum* L. and *Achillea millefolium* L. In Proceedings of the International Conference on Medicinal and Aromatic Plants. Possibilities and Limitations of Medicinal and Aromatic Plant, Budapest, Hungary, 8–11 July 2001; pp. 295–301.
- Eichelmann, H.; Oja, V.; Rasulov, B.; Padu, E.; Bichele, I.; Pettai, H.; Kasparova, M.I.; Laisk, A. Photosynthetic parameters of birch (*Betula pendula* Roth) leaves growing in normal and in CO₂- and O₃-enriched atmospheres. *Plant Cell Environ.* **2004**, *27*, 479–495. [CrossRef]
- Gebauer, A.D.; Brown, R.; Schwab, S.; Nezat, C.; McNeely, C. Effects of an invasive grass (*Phalaris arundinacea*) on water availability in semi-arid riparian zones. *Wetlands* **2016**, *36*, 59–72. [CrossRef]
- Jovanović, S.; Jakovljević, K.; Djordjević, V.; Vukojičić, S. Ruderal flora and vegetation of the town of Žabljak (Montenegro)—An overview for the period 1990–1998. *Bot. Serb.* **2013**, *37*, 55–69.
- Panitsa, M.; Iliadou, E.; Kokkoris, I.; Kallimanis, A.; Patelodimou, C.; Strid, A.; Raus, T.; Bergmeier, E.; Dimopoulos, P. Distribution patterns of ruderal plant diversity in Greece. *Biodivers. Conserv.* **2020**, *29*, 869–891. [CrossRef]
- Shem-Tov, S.; Fennimore, S.A. Seasonal changes in annual bluegrass (*Poa annua*) germinability and emergence. *Weed Sci.* **2003**, *51*, 690–695. [CrossRef]
- Hurley, P.T.; Emery, M.R. Locating provisioning ecosystem services in urban forests: Forageable woody species in New York City, USA. *Landsc. Urb. Plann.* **2018**, *170*, 266–275. [CrossRef]
- Pyšek, P.; Chocholousková, Z.; Pyšek, A.; Jarošík, V.; Chytrý, M.; Tichý, L. Trends in species diversity and composition of urban vegetation over three decades. *J. Veg. Sci.* **2004**, *15*, 781–788. [CrossRef]
- Chiuffo, M.C.; Cock, M.C.; Prina, A.O.; Hierro, J.L. Response of native and non-native ruderals to natural and human disturbance. *Biol. Invasions* **2018**, *20*, 2915–2925. [CrossRef]
- Yalçınalp, E.; Dihkan, A.; Meral, A.; Akbulut, S. The effects of habitat on the distribution of urban ruderal vegetation. *Braz. J. Bot.* **2023**, *46*, 1141–1151. [CrossRef]

16. Čepelová, B.; Münzbergová, Z. Factors determining the plant species diversity and species composition in a suburban landscape. *Landsc. Urb. Plan.* **2012**, *106*, 336–346. [\[CrossRef\]](#)
17. Jha, R.K.; Nölke, N.; Diwakara, B.N.; Tewari, V.P.; Kleinn, C. Differences in tree species diversity along the rural-urban gradient in Bengaluru, India. *Urb. For. Urb. Green.* **2019**, *46*, 126464. [\[CrossRef\]](#)
18. Wang, M.; Li, J.; Kuang, S.; He, Y.; Chen, G.; Huang, Y.; Song, C.; Anderson, P.; Łowicki, D. Plant diversity along the urban–rural gradient and its relationship with urbanization degree in Shanghai, China. *Forests* **2020**, *11*, 171. [\[CrossRef\]](#)
19. Kitazawa, T.; Ohsawa, M. Patterns of species diversity in rural herbaceous communities under different management regimes, Chiba, central Japan. *Biol. Conserv.* **2002**, *104*, 239–249. [\[CrossRef\]](#)
20. Güler, B. Plant species diversity and vegetation in urban grasslands depending on disturbance levels. *Biologia* **2020**, *75*, 1231–1240. [\[CrossRef\]](#)
21. Rega-Brodsky, C.C.; Aronson, M.F.J.; Piana, M.R.; Carpenter, E.-S.; Hahs, A.K.; Herrera-Montes, A.; Knapp, S.; Kotze, D.J.; Lepczyk, C.A.; Moretti, M.; et al. Urban biodiversity: State of the science and future directions. *Urb. Ecosyst.* **2022**, *25*, 1083–1096. [\[CrossRef\]](#)
22. Paltineanu, C.; Mihailescu, I.F.; Seceleanu, I.; Dragota, C.; Vasenciuc, F. Using aridity indices to describe some climate and soil features in Eastern Europe: A Romanian case study. *Theor. Appl. Climatol.* **2007**, *90*, 263–274. [\[CrossRef\]](#)
23. Mitrică, B.; Șerban, P.; Mocanu, I.; Grigorescu, I.; Damian, N.; Dumitrașcu, M. Social development and regional disparities in the rural areas of Romania: Focus on the social disadvantaged areas. *Soc. Indic. Res.* **2020**, *152*, 67–89. [\[CrossRef\]](#)
24. Google Earth. 2022. Available online: <https://earth.google.com> (accessed on 15 May 2024).
25. Braun-Blanquet, J. *Pflanzensoziologie: Grundzüge der Vegetationskunde*; Springer: Vienna, Austria; New York, NY, USA, 1964; 631p.
26. World Flora Online. Available online: <http://wfpplantlist.org/> (accessed on 20 February 2023).
27. Biță-Nicolae, C.; Sanda, V. *Cormophlora of Romania: Spontaneous and cultivated Cormophytes in Romania*; Lambert Academic Publishing: Saarbrücken, Germany, 2011.
28. Mucina, L.; Bültmann, H.; Dierßen, K.; Theurillat, J.; Raus, T.; Čarni, A.; Šumberová, K.; Willner, W.; Dengler, J.; García, R.G. Vegetation of Europe: Hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities. *Appl. Veg. Sci.* **2016**, *19*, 3–264. [\[CrossRef\]](#)
29. Sanda, V.; Öllerer, K.; Burescu, P. *Fitocenozele din România. Sintaxonomie, Structură, Dinamică Și Evoluție [Plant Associations of Romania. Syntaxonomy, Structure, Dynamics and Evolution]*; Ars Docendi Publishing House, Universitatea din București: București, Romania, 2008.
30. Past 4—The Past of the Future. Available online: <https://www.nhm.uio.no/english/research/resources/past/> (accessed on 30 March 2023).
31. Sanda, V. *Vademecum Ceno-Structural Privind Covorul Vegetal al României (Ceno-Structural Vademecum on the Romanian Vegetation, in Romanian)*; Vergiliu Press: București, Romania, 2002.
32. Antoniadis, V.; Shaheen, S.; Stärk, H.-J.; Wennrich, R.; Levizou, E.; Merbach, I.; Rinklebe, J. Phytoremediation potential of twelve wild plant species for toxic elements in a contaminated soil. *Environ. Int.* **2021**, *146*, 106233. [\[CrossRef\]](#) [\[PubMed\]](#)
33. Reeves, R.; Baker, A. Metal-Accumulating Plants. In *Phytoremediation of Toxic Metals: Using Plants to Clean up the Environment*; John Wiley: New York, NY, USA, 2000; p. 6.
34. Kumar, S.; Singh, R.; Kumar, V.; Rani, A.; Jain, R. Cannabis sativa: A Plant Suitable for Phytoremediation and Bioenergy Production. In *Phytoremediation Potential and Bioenergy Production*; Kumar, V., Ed.; Springer: Singapore, 2017. [\[CrossRef\]](#)
35. Bini, C.; Maleci, L.; Wahsha, M. The impact of former mining activity in the vicinity of an old mercury mine (Vallalta, Northern Italy). In Proceedings of the International Conference on Environment and Renewable Energy, Venice, Italy, 6–8 June 2018.
36. González, H.; Fernández-Fuego, D.; Bertrand, A.; Sánchez-López, M. Effect of pH and citric acid on the growth, arsenic accumulation, and phytochelatin synthesis in *Eupatorium cannabinum* L., a promising plant for phytostabilization. *Environ. Sci. Pollut. Res.* **2019**, *26*, 26242–26253. [\[CrossRef\]](#) [\[PubMed\]](#)
37. Kafle, A.; Timilsina, A.; Gautam, A.; Adhikari, K.; Bhattarai, A.; Aryal, N. Phytoremediation: Mechanisms, plant selection and enhancement by natural and synthetic agents. *Environ. Adv.* **2022**, *8*, 100203. [\[CrossRef\]](#)
38. Yu, C.; Peng, X.; Yan, H.; Li, X.; Zhou, Z.; Yan, T. Phytoremediation ability of *Solanum nigrum* L. to Cd-contaminated soils with high levels of Cu, Zn, and Pb. *Water Air Soil Pollut.* **2015**, *226*, 2424. [\[CrossRef\]](#)
39. Kano, N.; Hori, T.; Zhang, H.; Miyamoto, N.; Anak, D.E.V.; Mishima, K. Study on the behavior and removal of cadmium and zinc using *Taraxacum officinale* and *Gazania* under the application of biodegradable chelating agents. *Appl. Sci.* **2021**, *11*, 1557. [\[CrossRef\]](#)
40. D’Arco, M.; Ferroni, L.; Velli, A.; Speranza, M. Growth and spread of native perennial herbaceous species on a green roof. *Acta Hortic.* **2018**, *1215*, 237–246. [\[CrossRef\]](#)
41. Seyedabadi, M.; Eicker, U.; Karimi, S. Plant selection for green roofs and their impact on carbon sequestration and the building carbon footprint. *Environ. Chall.* **2021**, *4*, 100119. [\[CrossRef\]](#)
42. Erwin, J.; Hensley, J. Plants with horticultural and ecological attributes for green roofs in a cool, dry climate. *HortScience* **2019**, *54*, 1703–1711. [\[CrossRef\]](#)
43. Hawke, R. An evaluation study of plants for use on green roofs. *Plant Eval. Notes* **2015**, *38*, 1–22.
44. Jacobs, J.; Beenaerts, N.; Artois, T. Green roofs and pollinators, useful green spots for some wild bee species (Hymenoptera: Anthophila), but not so much for hoverflies (Diptera: Syrphidae). *Sci. Rep.* **2023**, *13*, 1449. [\[CrossRef\]](#)

45. Walters, S.A.; Stoelzle Midden, K. Sustainability of urban agriculture: Vegetable production on green roofs. *Agriculture* **2018**, *8*, 168. [\[CrossRef\]](#)
46. Piana, M.; Carlisle, S. Green Roof Plant Assemblage and Dynamics. In *Green Roof Ecosystems*; Sutton, R.K., Ed.; Springer International Publishing: Cham, Switzerland, 2015; pp. 285–310.
47. Grime, J.P. Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. *Am. Nat.* **1977**, *111*, 1169–1194. [\[CrossRef\]](#)
48. Hitchmough, J. Naturalistic herbaceous vegetation for urban landscapes. In *The Dynamic Landscape*; Taylor & Francis: Abingdon, UK, 2004; pp. 172–245.
49. Frouz, J.; Pižl, V.; Háněl, L.; Starý, J.; Tajovský, K.; Materna, J.; Balík, V.; Kalčík, J.; Řehounková, K. Interactions between soil development, vegetation and soil fauna during spontaneous succession in post mining sites. *Eur. J. Soil Biol.* **2008**, *44*, 109–121. [\[CrossRef\]](#)
50. Gail, L.; Andony, M.; Isabella, M.; Aaron, A.; Nathan, M.; Lucas, C. Garden Pollinators and the potential for ecosystem service flow to urban and peri-urban agriculture. *Sustainability* **2018**, *10*, 2047. [\[CrossRef\]](#)
51. Chiuffo, M.C.; MacDougall, A.S.; Hierro, J.L. Native and non-native ruderals experience similar plant–soil feedbacks and neighbor effects in a system where they coexist. *Oecologia* **2015**, *179*, 843–852. [\[CrossRef\]](#)
52. Sukopp, H.; Wurzel, A. Changing climate and the effects on vegetation in central European cities. *Arboric. J.* **2000**, *24*, 257–281. [\[CrossRef\]](#)
53. Hipps, N.A.; Davies, M.J.; Dodds, P.; Buckley, G.P. The effects of phosphorus nutrition and soil pH on the growth of some ancient woodland indicator plants and their interaction with competitor species. *Plant Soil* **2005**, *271*, 131–141. [\[CrossRef\]](#)
54. Rebele, F. Vegetation development on deposit soils starting at different seasons. *Plant Ecol.* **2008**, *195*, 1–12. [\[CrossRef\]](#)
55. Biondi, E.; Casavecchia, S.; Pesaresi, S. Nitrophilous and ruderal species as indicators of climate change. Case study from the Italian Adriatic coast. *Plant Biosyst.* **2012**, *146*, 134–142. [\[CrossRef\]](#)
56. Crawley, M.J. Timing of disturbance and coexistence in a species-rich ruderal plant community. *Ecology* **2004**, *85*, 3277–3288. [\[CrossRef\]](#)
57. Roem, W.J.; Berendse, F. Soil acidity and nutrient supply ratio as possible factors determining changes in plant species diversity in grassland and heathland communities. *Biol. Conserv.* **2000**, *92*, 151–161. [\[CrossRef\]](#)
58. Morecroft, M.D.; Paterson, J.S. Effects of Temperature and Precipitation Changes on Plant Communities. In *Plant Growth and Climate Change*; Morison, J.I.L., Morecroft, M.D., Eds.; Wiley: Hoboken, NJ, USA, 2006; pp. 146–164. [\[CrossRef\]](#)
59. Tabašević, M.; Jovanović, S.; Lakušić, D.; Vukojičić, S.; Kuzmanović, N. Diversity of ruderal communities in urban environments—A case study from Serbia (SE Europe). *Diversity* **2021**, *13*, 638. [\[CrossRef\]](#)
60. Myśliwy, M.; Pešić, V. Tall herb fringe vegetation on banks of Montenegrin Rivers as a habitat type of European importance. *Water* **2023**, *15*, 3684. [\[CrossRef\]](#)
61. Biță-Nicolae, C.; Indreica, A. *Artemisia vulgaris* in Romania—An Overview. *Plant Biosyst. Int. J. Deal. Asp. Plant Biol.* **2016**, *150*, 512–518. [\[CrossRef\]](#)
62. Molina, J.A.; Martín-Sanz, J.P.; Casermeiro, M.Á.; Quintana, J.R. Spontaneous urban vegetation as an indicator of soil functionality and ecosystem services. *Appl. Veg. Sci.* **2023**, *26*, e12827. [\[CrossRef\]](#)
63. Carvell, C.; Meek, W.; Pywell, R.; Goulson, D.; Nowakowski, M. Comparing the efficacy of agri-environment schemes to enhance bumblebee abundance and diversity on arable farmland. *J. Appl. Ecol.* **2006**, *44*, 29–40. [\[CrossRef\]](#)
64. Pille, L.; Säume, I. The water-sensitive city meets biodiversity: Habitat services of rain water management measures in highly urbanized landscapes. *Ecol. Soc.* **2021**, *26*, 23. [\[CrossRef\]](#)
65. Benedec, D.; Vlase, L.; Oniga, I.; Mot, A.C.; Damian, G.; Hanganu, D.; Duma, M.; Silaghi-Dumitrescu, R. Polyphenolic composition, antioxidant and antibacterial activities for two Romanian subspecies of *Achillea distans* Waldst. et Kit. ex Willd. *Molecules* **2013**, *18*, 8725–8739. [\[CrossRef\]](#) [\[PubMed\]](#)
66. Chevallier, A. *The Encyclopedia of Medicinal Plants: An Excellent Guide to Over 500 of the More Well-Known Medicinal Herbs from around the World*; Dorling Kindersley: London, UK, 1996.
67. Tozyo, T.; Yoshimura, Y.; Sakurai, K.; Uchida, N.; Takeda, Y.; Nakai, H.; Ishii, H. Novel antitumor sesquiterpenoids in *Achillea millefolium*. *Chem. Pharm. Bull.* **1994**, *42*, 1096–1100. [\[CrossRef\]](#) [\[PubMed\]](#)
68. Marinas, I.; Oprea, E.; Gaboreanu, D.; Pircalabioru, G.; Buleandra, M.; Nagoda, E.; Badea, I.; Chifiriuc, M. Chemical and biological studies of *Achillea setacea* herba essential oil—First report on some antimicrobial and antipathogenic features. *Antibiotics* **2023**, *12*, 371. [\[CrossRef\]](#) [\[PubMed\]](#)
69. Jakubczyk, K.; Janda-Milczarek, K.; Styburski, D.; Lukomska, A. Goutweed (*Aegopodium podagraria* L.)—Botanical characteristics and prohealthy properties. *Postęp. Hyg. Med. Dośw.* **2020**, *74*, 28–35. [\[CrossRef\]](#)
70. Pawłowska, K.; Hałas, R.; Dudek (Jamróz), M.; Majdan, M.; Jankowska, K.; Granica, S. Antibacterial and anti-inflammatory activity of bistort (*Bistorta officinalis*) aqueous extract and its major components. Justification of the usage of the medicinal plant material as a traditional topical agent. *J. Ethnopharmacol.* **2020**, *260*, 113077. [\[CrossRef\]](#)
71. Saar-Reismaa, P.; Bragina, O.; Kuhtinskaja, M.; Reile, I.; Laanet, P.-R.; Kulp, M.; Vaher, M. Extraction and fractionation of bioactives from *Dipsacus fullonum* L. leaves and evaluation of their anti-Borrelia activity. *Pharmaceuticals* **2022**, *15*, 87. [\[CrossRef\]](#)
72. Duke, J.A. *Handbook of Medicinal Herbs*, 2nd ed.; CRC Press: Boca Raton, FL, USA, 2002. [\[CrossRef\]](#)

73. Aggarwal, G.; Kaur, G.; Bhardwaj, G.; Mutreja, V.; Sohal, H.S.; Nayik, G.A.; Bhardwaj, A.; Sharma, A. Traditional uses, phytochemical composition, pharmacological properties, and the biodiscovery potential of the genus *Cirsium*. *Chemistry* **2022**, *4*, 1161–1192. [\[CrossRef\]](#)
74. Botalova, A.; Bombela, T.; Zubov, P.; Segal, M.; Korkotian, E. The flavonoid acetylpectolinarin counteracts the effects of low ethanol on spontaneous network activity in hippocampal cultures. *J. Ethnopharmacol.* **2019**, *229*, 22–28. [\[CrossRef\]](#)
75. Radulović, N.S.; Mladenović, M.Z.; Vukićević, D.R.; Stojanović, N.M.; Randjelović, P.J.; Stojanović-Radić, Z.Z.; Boylan, F. *Pulicaria dysenterica* (L.) Bernh.—Rightfully earned name? Identification and biological activity of new 3-methoxycuminylnyl esters from *P. dysenterica* essential oil. *Plants* **2022**, *11*, 3340. [\[CrossRef\]](#)
76. Díaz, K.; Espinoza, L.; Madrid, A.; Pizarro, L.; Chamy, R. Isolation and identification of compounds from bioactive extracts of *Taraxacum officinale* Weber ex F. H. Wigg. (Dandelion) as a potential source of antibacterial agents. *Evid. Based Complement. Alternat. Med.* **2018**, *2018*, 2706417. [\[CrossRef\]](#)
77. Kong, Y.D.; Qi, Y.; Cui, N.; Zhang, Z.H.; Wei, N.; Wang, C.F.; Zeng, Y.N.; Sun, Y.P.; Kuang, H.X.; Wang, Q.H. The traditional herb *Polygonum hydropiper* from China: A comprehensive review on phytochemistry, pharmacological activities and applications. *Pharm. Biol.* **2023**, *61*, 799–814. [\[CrossRef\]](#) [\[PubMed\]](#)
78. Najafian, Y.; Hamed, S.S.; Farshchi, M.K.; Feyzabadi, Z. *Plantago major* in traditional Persian medicine and modern phytotherapy: A narrative review. *Electron. Physician* **2018**, *10*, 6390–6399. [\[CrossRef\]](#) [\[PubMed\]](#)
79. Pol, M.; Schmidtke, K.; Lewandowska, S. *Plantago lanceolata*—An overview of its agronomically and healing valuable features. *Open Agric.* **2021**, *6*, 479–488. [\[CrossRef\]](#)
80. Budzianowska, A.; Derda, M.; Budzianowski, J.; Szopa, A.; Kikowska, M. Comparative study of *Plantago media* extracts in the treatment of *Acanthamoeba* sp. Trophozoites. *Appl. Sci.* **2023**, *13*, 7075. [\[CrossRef\]](#)
81. Kenari, H.M.; Kordafshari, G.; Moghimi, M.; Eghbalian, F.; TaherKhani, D. Review of pharmacological properties and chemical constituents of *Pastinaca sativa*. *J. Pharmacopunct.* **2021**, *24*, 14–23. [\[CrossRef\]](#)
82. Shabih, S.; Hajdari, A.; Mustafa, B.; Quave, C.L. Chapter 3—Medicinal Plants in the Balkans with Antimicrobial Properties. In *Medicinal Plants as Anti-Infectives*; Chassagne, F., Ed.; Academic Press: Cambridge, MA, USA, 2022; pp. 103–138, ISBN 9780323909990.
83. Denisow, B. *Pollen Production of Selected Ruderal Plant Species in the Lublin Area*; University of Life Sciences in Lublin Press: Lublin, Poland, 2011; Volume 351, p. 86.
84. Nichols, R.N.; Goulson, D.; Holland, J.M. The best wildflowers for wild bees. *J. Insect Conserv.* **2019**, *23*, 819–830. [\[CrossRef\]](#)
85. Denisow, B.; Wrzesień, M. The anthropogenic refuge areas for bee flora in agricultural landscape. *Acta Agrobot.* **2007**, *60*, 147–157. [\[CrossRef\]](#)
86. Boix-Fayos, C.; Martínez-Mena, M.; Arnau-Rosalén, E.; Calvo-Cases, A.; Castillo, V.; Albaladejo, J. Measuring soil erosion by field plots: Understanding the sources of variation. *Earth Sci. Rev.* **2006**, *78*, 267–285. [\[CrossRef\]](#)
87. Jim, C.Y. Sustainable urban greening strategies for compact cities in developing and developed economies. *Urb. Ecosyst.* **2013**, *16*, 741–761. [\[CrossRef\]](#)
88. Kleyer, M. Enhancing landscape planning: Vegetation-mediated ecosystem services predicted by plant traits. *Landsc. Urb. Plan.* **2021**, *215*, 104220. [\[CrossRef\]](#)
89. Palliwoda, J.; Banzhaf, E.; Priess, J.A. How do the green components of urban green infrastructure influence the use of ecosystem services? Examples from Leipzig, Germany. *Landsc. Ecol.* **2020**, *35*, 1127–1142. [\[CrossRef\]](#)
90. Jansen, J.; Hobohm, C. Urban Habitats: Cities and Their Potential for Nature Protection. In *Perspectives for Biodiversity and Ecosystems*; World Bank Group: Washington, DC, USA, 2021; pp. 425–447.
91. Mogîldea, E.D.; Mitoi, M.E.; Biță-Nicolae, C.; Murariu, D. Urban flora riches: Unraveling metabolic variation long altitudinal gradients in two spontaneous plant species. *Plants* **2024**, *13*, 657. [\[CrossRef\]](#) [\[PubMed\]](#)
92. Sukopp, H. Human-caused impact on preserved vegetation. *Landsc. Urb. Plan.* **2004**, *68*, 347–355. [\[CrossRef\]](#)
93. Kowarik, I.; Fischer, L.K.; Kendal, D. Biodiversity conservation and sustainable urban development. *Sustainability* **2020**, *12*, 4964. [\[CrossRef\]](#)

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.