






Spontaneous Flora of Urban Domestic Gardens of the City of Sarajevo

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Abstract. Gardens around private houses are complex urban habitats, and generally consist of a mosaic of different microhabitats including hedges, paved surfaces, lawns, flowerbeds, fruit trees, vegetable patches and areas of uncultivated land. Although their individual size is small, domestic gardens significantly contribute to the overall flora of the urban areas. The floristic composition of domestic gardens is influenced by both natural processes and by the activities of the owners, who shape them according to their own preferences, depending on culture and lifestyle. Domestic gardens have not been represented in ecological studies until recently, primarily due to lack of access and were deliberately omitted, but it has been showed that they represent the greatest source of potentially invasive alien plants. This study, conducted in the area of 32 km², as a part of a wider study of the urban flora of the city of Sarajevo, presents the first detailed analysis of the spontaneous flora in the domestic gardens and provides new knowledge on the flora of this, often overlooked, habitat.

Keywords: Domestic Gardens · Sarajevo · Floristic Composition · Urbanization

1 Introduction

The term domestic gardens (home gardens, backyard gardens, kitchen gardens, doorway gardens, household gardens) refers to small patches of ground, associated with residential (owned or rented) homes, often delimited from their surroundings by hedges, walls, fences or other barriers [1]. Domestic gardens are complex habitats, and generally comprise paved paths and patios, lawns, flowerbeds, vegetable patches, various shrubs and trees, and in some cases a pond or fountain, a greenhouse, as well as uncultivated and neglected grounds, and a composting area [2, 3].

Although each garden individually occupies a small area, the total contribution of this type of habitat to the total green areas of the city can be substantial and constitute 16–36% of the total urban area [2, 4–7]. Species diversity in domestic gardens is often determined by a combination of environmental, cultural and socio-economic factors [8–10], and is directly influenced by the owners, who shape them according to their own discretion depending on culture, lifestyle and aesthetic preferences [11, 12]. Domestic gardens contribute significantly to the total number of plant taxa in urban environments,

and are also a key site for introduction of non-native plants, including the invasive taxa [2, 13, 14].

Generally, horticultural practice promotes the use of low-maintenance plants [11], and is the main pathway for the introduction of alien taxa. Ornamental plants comprise more than 40% of widespread invasive plant taxa [15]. As domestic gardens are the places where alien taxa that escaped cultivation often occur first, the study of spontaneous domestic garden floras is interesting with respect to potential spread of alien taxa. Since most domestic gardens are located in the peripheral parts of the urban areas, close to the natural vegetation, there is a high rate of species exchange between gardens and their surroundings [16], and acquiring knowledge about the floristic composition of the domestic gardens could anticipate the spread of alien taxa and changes in biodiversity of natural plant communities. Domestic gardens are also regarded as an important habitat for managing and conserving biodiversity, including rare, endangered or endemic taxa [7, 8].

Private gardens have not been represented in ecological studies until recently [2, 17–19], primarily due to lack of access and were deliberately omitted in surveys of urban floras. The study of home gardens was initiated in the tropics of South East Asia [20], and most available data are from tropical Asia and Central America [8, 10, 21–26] and Africa [27–29], but these are mainly focused on role of domestic gardens as sustainable agroforestry systems.

To our knowledge, home-gardens in cities have not been systematically studied in Bosnia and Herzegovina, and this paper attempts to describe and analyze the flora of domestic gardens from an urban environment, with focus on alien taxa and taxa of conservational interest. We also analyzed if the floristic similarity between gardens changes according to the urbanization gradient (i.e. with the distance from the center of the urbanized area).

2 Materials and methods

2.1 Surveyed Area

The survey was performed from the summer of 2015 to the autumn of 2021, in the gardens of private, owner-occupied dwellings in the urban part of the city of Sarajevo (Fig. 1), in an area of 32 km² within the administrative boundary of the city, in 1 × 1 km grid cells with more than 25% coverage by residential or industrial zones [2, 3]. The plants were recorded by surveying the entire domestic garden area, where it was possible, or by observing the area from the street or nearby path, if the access to the garden was not granted by the owners. The survey was carried out using an ad-hoc method, which consists in examining the site until it is subjectively concluded that no more species can be found there [30]. Only the spontaneous flora (native taxa, and aliens that were observed growing as seedlings, in a places outside the ones where they were originally planted or sown) was recorded. Cultivars were not considered as separate taxa.

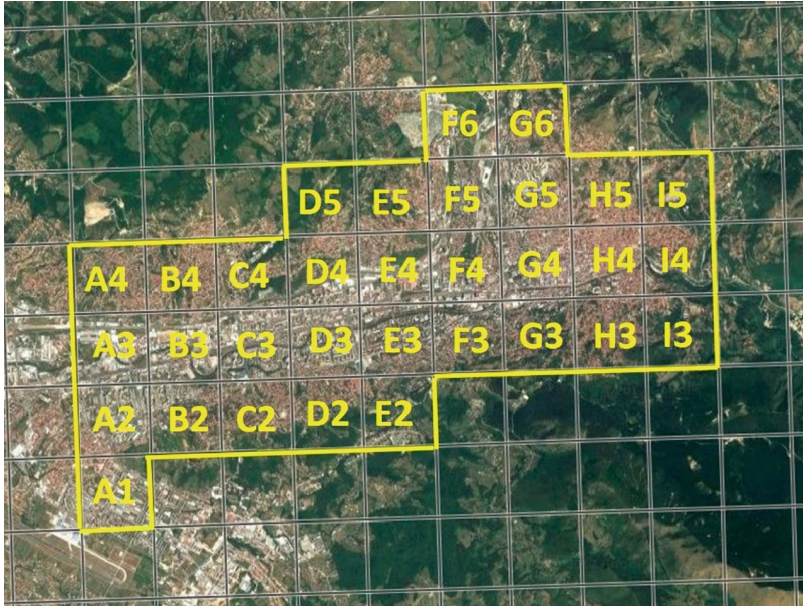


Fig. 1. Surveyed area

2.2 Data Analysis

The nomenclature follows the Euro + Med PlantBase [31]. The data on the life forms is taken from Flora of Italy [32, 33], with categories based on the classification of Raunkiaer [34].

The taxa were classified into floral elements [35], and assigned alien or native status [36, 37]. Alien taxa were further classified according to their residence time, mode of introduction and geographic origin [37, 38], as well as the degree of naturalization [38–40]. The native taxa were assigned endemic [41], and conservation status [42]. The data on the affinity towards the conditions that prevail in urban environments were taken from the BiolFlor database [43].

The scope of anthropogenic changes of the flora was assessed using the indicators based on proportions between individual geographical-historical groups[44–46]:

1. Indicators of anthropization.
 - 1.1. Indicator of total anthropization, $I_{Ant} = \frac{An}{(Sp + An)} \times 100$;
 - 1.2. Indicator of permanent anthropization, $I_{Anp} = \frac{Mt}{(Sp + Mt)} \times 100$;
2. Indicators of archaeophytization.
 - 2.1. Indicator of total archaeophytization, $I_{Art} = \frac{Ar}{(Sp + An)} \times 100$;
 - 2.2. Indicator of permanent archaeophytization, $I_{Arp} = \frac{Ar}{(Sp + Mt)} \times 100$;
3. Indicators of kenophytization.
 - 3.1. Indicator of total kenophytization, $I_{Knt} = \frac{Kn}{(Sp + An)} \times 100$;
 - 3.2. Indicator of permanent kenophytization, $I_{Knp} = \frac{Kn}{(Sp + Mt)} \times 100$.
4. Indicator of flora modernization, $I_M = \frac{Kn}{Mt} \times 100$;
5. Indicator of fluctuation changes, $I_F = \frac{Df}{(Sp + An)} \times 100$;

where An is number of alien taxa; Sp – number of native taxa; Mt – number of permanently established alien taxa ($Ar + Kn - Df$), Ar – number of archaeophytes, Kn – number of neophytes, Df – number of casual alien taxa.

To examine the floristic similarity along the urbanization gradient, similarity of 1 × 1 km squares was calculated based on the Bray-Curtis cluster analysis using the PAST software [47].

3 Results and Discussion

During this research, a total of 505 species of 296 genera and 76 families were recorded. The most abundant families were *Compositae* (67 taxa, 13.27%), *Poaceae* (52 taxa, 10.3%) and *Fabaceae* (35 taxa, 6.93%). These families are the most numerous in the total vascular flora of Bosnia and Herzegovina [48]. The flora of domestic gardens in England [4] and France [49] is dominated by *Compositae* and *Rosaceae*, probably due to the fact that deliberately planted ornamentals and fruit trees and shrubs (most of which are *Rosaceae*) were included in these analyses. Out of 76 families recorded in domestic gardens in Sarajevo, 23 (30.36%) were represented by only a single species, 16 of which were native, and 7 alien. The number of taxa in domestic gardens in Sarajevo is in accordance to the data given in the available literature sources, which ranges from 208, as recorded in Marseille (France) [6], to 1166 in Sheffield (England) [4]. The large number of plant taxa in gardens is a result of the fact that in most domestic gardens, nutrients and water are constantly added to the soil, enabling the survival of plants in places where it would not otherwise be possible [18].

The analysis of life forms showed the domination of hemicryptophytes (244 taxa, 48.32%), followed by therophytes (25.54%), phanerophytes (11.68%), geophytes (8.32%), and chamaephytes (6.14%). Hydrophytes were not recorded among the spontaneous taxa. The domination of hemicryptophytes and therophytes was also noted in weed flora of gardens in settlements in around Plešivica mountain in Croatia [50].

Most of the taxa found in the domestic gardens of Sarajevo naturally occur in Bosnia and Herzegovina (86.93% of the garden flora). The share of alien taxa (13.07%) is much smaller than in this habitat type in other cities worldwide. For example, in Minneapolis–Saint Paul in Minnesota (USA), 59% of all spontaneous yard taxa were exotic [51], an average of 71% alien taxa was calculated for domestic gardens in 5 cities in Great Britain [3], and an average of 40% for 54 Central European cities [52]. In private gardens in Lauris and Marseille, there were 13% and 10% alien taxa, respectively [6]. The high ratio of alien taxa in private gardens worldwide is a result of the horticultural practices, which promote the planting of hardy and aesthetically pleasing non-native plants [1]. In Sarajevo, however, most domestic gardens are located in the peripheral part of the city, on the slopes of hills surrounding the city, where the local microclimate due to the higher altitude prevents the development of taxa originating from warmer regions. Numerous domestic gardens in Sarajevo also include a traditionally managed vegetable patches and small orchards, and parts of unmanaged or neglected ground, where the development of native vegetation is encouraged.

Out of 66 alien taxa observed during this survey, 47 (71.21%) are naturalized and 21 (31.82% of total number of alien taxa) invasive. Alien flora of domestic gardens

of Sarajevo is dominated by neophytes (38 taxa or 57.57%). The ratio of neophytes to archaeophytes increases in direct relation to the intensity of human disturbance [53], as archaeophytes are typically associated with traditional rural environments or intermediate levels of anthropogenic activities, while neophytes are more common in highly disturbed habitats, which provide distinctive environmental conditions that favor the establishment of plant taxa from warmer and drier areas [40, 52, 54, 55]. The neophyte/archaeophyte ratio in domestic garden flora of Sarajevo (1.52) indicates the high intensity of anthropogenic disturbance in this urban habitat type.

According to the mode of introduction, most alien taxa (42 or 63.64%) found during this survey were deliberately introduced in Balkan region and/or in Europe, mostly as ornamentals, or various crops, including fruit trees and vines. Some of these "planta hortifuga" [56] tend to escape the cultivation and establish their populations in fringe vegetation, as on the riparian habitats and banks, roadsides, along forest edges, on wasteyards, old walls, debris and also on arable fields.

During this survey, some of invasive neophytes introduced as ornamentals (*Reynoutria japonica* Houtt., *Acer negundo* L. *Ailanthus altissima* (Mill.) Swingle, *Helianthus tuberosus* L., *Impatiens balfourii* Hooker f., *Parthenocissus quinquefolia* (L.) Planchon, *Robinia pseudoacacia* L., *Solidago gigantea* Aiton), were observed to invade the natural or seminatural vegetation. Still, these taxa are either deliberately planted and grown in many surveyed gardens, or not removed in their seedling stages. Given the fact that most domestic gardens in Sarajevo are located in the peripheral parts of the city, it is possible that these plant taxa can become troublesome invaders particularly on dry, rocky or gravelly soils, or in riparian habitats such as are the ones found in the protected area of Bentbaša, located in the western part of the surveyed area.

The high number of seedlings of *Rhus typhina* L. was observed during this survey. This neophyte is listed as invasive in Belgium [57] and Serbia [58], and has not reached its maximum range yet, so its spread should be monitored.

Most accidentally introduced taxa are agricultural weeds (e.g. *Amaranthus retroflexus* L., *Ambrosia artemisiifolia* L., *Datura stramonium* L., *Erigeron canadensis* L., *E. annuus* (L.) Pers., *Galinsoga parviflora* Cav., *G. quadriradiata* Ruiz & Pav., *Papaver rhoeas* L., *Veronica persica* Poir....), which can be explained by the fact that some of the surveyed domestic gardens comprise parts in which the traditional agricultural practices are still present (vegetable patches or orchards).

The analysis of floral elements of domestic garden flora of Sarajevo (Fig. 2) shows the dominance of widespread taxa (29.89%), followed by taxa of Eurasian (25.84%) and South European (13.93%) floral element. The ratio of cultivated and adventitious plants is rather low (9.89%), which is in accordance to the low percentage of alien taxa in the overall flora. Widespread and Eurasian taxa were the most numerous in garden communities in Plešivica hills in Croatia as well [50]. The domination of Eurasian taxa in both cases can be explained by the geographic location of the surveyed area, and the widespread taxa have fewer specific environmental preferences and tend to have a higher affinity to urban areas [59].

Most alien taxa (31.52%) originate from Asia, followed by taxa from other parts of Europe, mostly Mediterranean (Fig. 3). American taxa constitute 27.17% of alien flora (including 18.48 taxa from North America, 4.35 taxa from Central America and 4.35

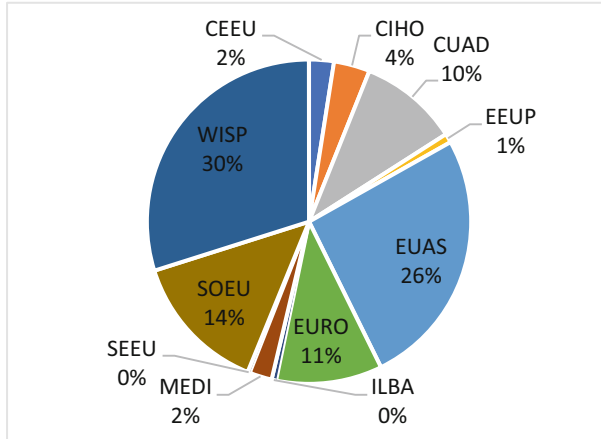


Fig. 2. Spectrum of floral elements (%) of domestic garden flora of Sarajevo (MEDI – Mediterranean floral element, ILBA – Illyrian-Balkan floral element, SOEU – South European floral element, EEUP – East European-Pontic floral element, SEEU – Southeast European floral element, CEEU – Central European floral element, EURO – European floral element, EUAS – Eurasian floral element, CIHO – Circum-Holarctic floral element, WISP – widespread plants, CUAD – cultivated and adventitious plants).

taxa from South America), and mostly include deliberately introduced ornamentals. In domestic gardens in 5 cities in the United Kingdom, the largest number of alien plant taxa was of European or Asian origin, and fewer were from North and South America, Africa and Australia [3].

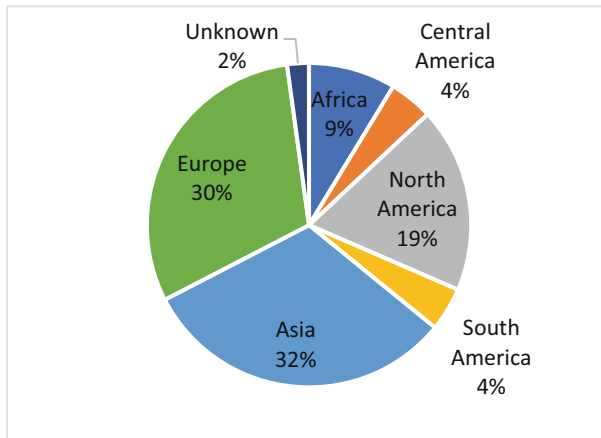


Fig. 3. Geographic origin of the alien flora observed in the domestic gardens in Sarajevo

The flora of domestic gardens is dominated by moderately urbanophobic taxa (37.04%), followed by urbanoneutral (28.27%), urbanophobic (20.99%), moderately

urbanophilic (9.85%), and only 3.85% taxa observed in this habitat type is urbanophilic (Fig. 4), which indicates the high level of naturalness in flora of domestic gardens in Sarajevo.

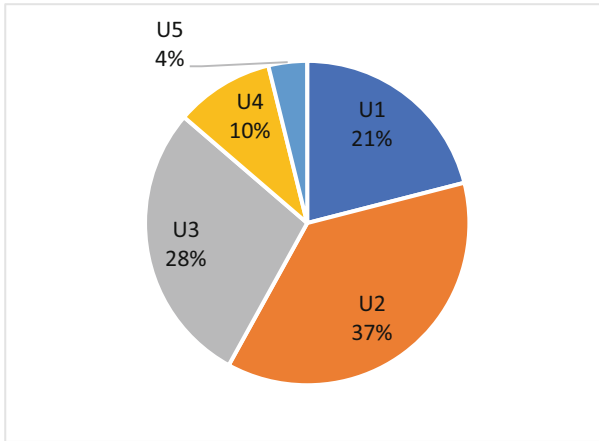


Fig. 4. The affinity of domestic garden taxa towards the conditions that prevail in urban environments (U1 – urbanophobic, U2 – moderately urbanophobic, U3 – urbanoneutral, U4 – moderately urbanophilic, U5 – urbanophilic)

The values of indicators of anthropogenic changes are presented in Table 1. The indicators of anthropophytization ($IAN_t = 13.07\%$; $IAN_p = 9.67\%$) show the considerable anthropogenic influence on the total flora of domestic gardens in Sarajevo. Higher indicator values of kenophytization ($IKn_t = 7.52\%$; $IKn_p = 7.82\%$) showed that the flora of the domestic gardens is more influenced by neophytes than by archaeophytes ($IAR_t = 4.95\%$; $IAR_p = 5.14\%$). In both archaeophytes and neophytes, the values of total and permanent indicators were similar, showing that alien flora is well established, which was confirmed by the low value of the indicator of fluctuating changes ($IF = 3.76\%$).

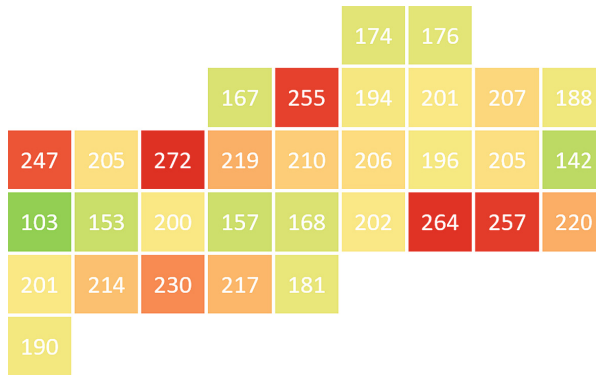
Endemic and endangered taxa represent only a small portion of the garden flora of Sarajevo. During this survey, one endemic taxon (*Trifolium dalmaticum* Vis.), and three taxa protected by the Red List of wild species and subspecies of plants, animals and fungi of Federation of Bosnia and Herzegovina, of which *Convallaria majalis* L. is listed as Near Threatened (NT), *Cephalanthera longifolia* (L.) Fritsch as Vulnerable (VU), and *Scabiosa cinerea* Lam. as Data Deficient (DD) species were found. The presence of these rare and endangered taxa in domestic gardens highlights the role that such land use types can fulfil in the conservation of local biodiversity. If we consider the fact that a substantial part of domestic gardens was not surveyed because of privacy issues, we can argue that this number is much higher. However small the contribution of individual domestic gardens may be towards the protection of such taxa, the collective effort of this habitat type across an entire urban ecosystem and also globally holds a large potential [2, 60].

The analysis of floristic similarity along the urbanization gradient indicates that the species richness is bigger in domestic gardens located in squares at the periphery of the

Table 1. Indicators of anthropogenic changes in the domestic garden flora of Sarajevo

Indicator	Value
IAn _t	13.07
IAn _p	9.67
IAr _t	4.95
IAr _p	5.14
IKn _t	7.52
IKn _p	7.82
IM	80.85
IF	3.76

surveyed area (Fig. 5). The exception are the squares located in the very north of the surveyed area (F6, G6), which cover mostly industrial zones, city graveyards and parks, and I4 and I5, which include substantial part of natural vegetation, and in which most houses are enclosed by tall walls, which did not allow the systematic survey of gardens. These results still demonstrate the decrease in floristic similarity along the urbanization gradient, as was found in Lauris and Marseille [6].

**Fig. 5.** Total number of taxa in gardens in 1 × 1 km squares in surveyed area

The overall floristic composition of gardens in individual squares shows that their diversity is more influenced by the geographic location within the urbanized area, as the squares which are located next to each other, and the ones that have the same distance from the urban center show higher similarity (Fig. 6).

Out of 505 taxa recorded during this survey, only 41 (8.12%) were found in all 32 1 km² squares. Only two of these (*Veronica persica* Poir. And *Capsella bursa-pastoris* (L.) Medik.) are alien. A total of 39 taxa (7.72%), including five aliens (*Catalpa bignonioides* Walter, *Cydonia oblonga* Mill., *Syringa vulgaris* L., *Ricinus communis* L., *Symphoricarpos albus* (L.) S.F. Blake) were observed spontaneously growing in only one

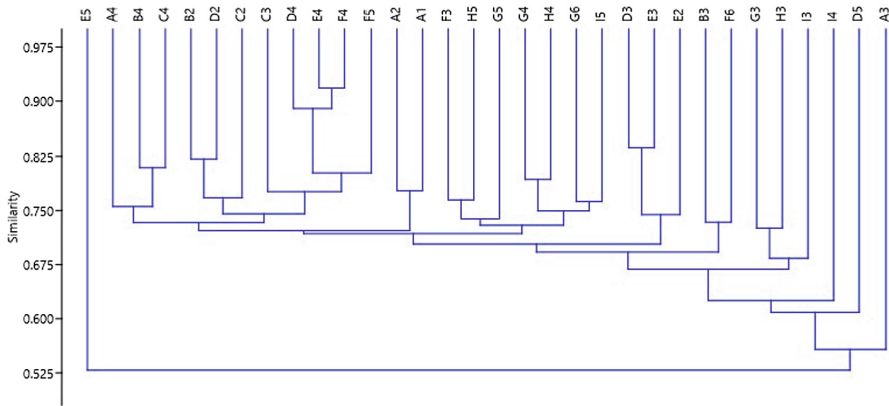


Fig. 6. Dendrogram constructed according to the list of plant taxa observed in domestic gardens in individual 1×1 km squares (similarity ratio, absence-presence data)

square. The fact that very small number of taxa were recorded only once indicates the low species turnover, and shows the uniformity of domestic garden flora in the surveyed area. These results differ from the ones reported for the gardens of Sheffield in England [1], which probably can be explained by the gardening practices and the fact that they included both spontaneous and cultivated taxa.

4 Conclusions

During the first systematic survey of domestic garden flora of the city of Sarajevo, a total of 505 species of 296 genera and 76 families were recorded. *Compositae*, *Poaceae* and *Fabaceae* were the most abundant families. Hemicryptophytes and therophytes are the most numerous life forms. Alien flora consists of 66 taxa, including 21 invasive, and is dominated by neophytes, which indicates high disturbance rate, and is supported by the fact that most of these taxa were deliberately introduced as ornamentals. Unlike most other cities, garden flora of Sarajevo is dominated by native taxa, and has a very low share of urbanophilic taxa, which indicates the high level of naturalness. One endemic and three protected taxa were found. However, the anthropogenic influence on the total flora of domestic gardens in Sarajevo is considerable. As some of the invasive and potentially invasive neophytes were observed to invade the natural and seminatural vegetation, but are still grown in gardens, there is the need to raise general awareness about the dangers these plant pose to the natural plant communities. More taxa were found in domestic gardens located at the edge of the urban area. Although the role of the homeowners in shaping the garden is important, the floristic diversity in Sarajevo is more influenced by the geographic location within the urbanized area. The results of this research may be used for assessing the risk of spreading cultivated plants, but also to indicate the importance of this habitat type for local biodiversity conservation.

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