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Articles

Urban floristic diversity in the arid zone: a case study of Bukhara city

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The urban flora of Bukhara city has experienced a surge in recent years, attributed to the introduction of adventive plants from abroad. We conducted detailed floristic descriptions of green spaces along roads, near houses, in the central city Samonid recreation park, and at the "Ko'hna va boqiy Buxoro" recreation center. We registered that urban vegetation comprises 42 species of trees, 21 species of shrubs, and 70 species of herbaceous vegetation. The density of urban phytocenoses in the surveyed areas ranges from 40 to 55 species per 1000 m2, encompassing 21–28 tree species, 4–11 shrub species, and 14–28 herb species. Our findings indicate that the introduced vegetation comprises 79 species from 34 families, with ornamental trees (43 species) and shrubs (24 species). We have observed a steady increase in the number of introduced species entering the city through natural means, suggesting their successful acclimatization despite the arid conditions. The research emphasized the importance of green spaces in promoting social cohesion, community well-being, and preserving cultural heritage in Bukhara. Additionally, the study indicated a steady increase in the number of introduced species entering the city through natural means, reflecting ongoing beautification efforts and urban development projects. Overall, the qualitative data provided insights into the resilience and adaptability of urban flora in Bukhara, the impact of urbanization on plant diversity, and the significance of green spaces in enhancing the quality of urban environments. The patterns and trends observed in the qualitative data underscore the need for sustainable management strategies to conserve and enhance biodiversity in Bukhara city.

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Keywords

Floristic diversity, flora, minimum range, botanical-geographical method

Introduction

In the realm of global climate change in the 21st century, the study of biodiversity has become increasingly important (A Global Standard 2016; Gulamov 2022; Kate 2022; Alves 2024). The vegetation in urban areas plays a vital role in public health and the overall well-being of city residents (Klausnitzer 1982; 1983; Vershinin 2014; Esanov 2016). Gardens and parks in cities significantly influence urban environments, creating favorable conditions for plant communities to thrive, especially in areas affected by human activities.

The urban vegetation has been the subject of several studies in recent years, with researchers exploring various aspects of plant diversity, distribution, and ecosystem services in the city. This literature review aims to synthesize and summarize the existing knowledge on urban vegetation to provide a comprehensive overview of the field. One of the key themes that emerge from the literature is the importance of urban vegetation in providing ecosystem services to the city's residents. A study by Ceplová et al. (2017) found that urban green spaces play a crucial role in regulating the local climate, reducing air pollution, and improving overall well-being. Similarly, Grapow, Blasti (1998) highlighted the role of urban vegetation in enhancing biodiversity and providing habitat for wildlife in the city.

Several studies have also focused on the distribution and composition of urban vegetation. For example, a study by Tretyakova et al. (2018) found that the city's parks and gardens are home to a diverse range of plant species, with a high level of endemism. In contrast, a study by Jovanović, Glišić (2021) reported a decline in native vegetation cover in urban areas due to urbanization and land use change.

In addition to ecosystem services and biodiversity, researchers have also explored the social and cultural significance of urban vegetation. A study by Tretyakova et al. (2021) highlighted the role of green spaces in promoting social cohesion and community well-being in the city. Similarly, Vähä-Piikkiö et al. (2004) found that urban vegetation plays a crucial role in preserving the city's cultural heritage and historical identity.

Various studies on urban vegetation diversity take into account factors such as the city's location, size, landscape, and geographical features, which impact the selection of suitable habitats (Christenhusz et al. 2011; Vershinin 2014; Brauneder et al. 2018; Prokhorov, Usmanova 2018). A crucial aspect of studying urban flora is determining its minimum range, which acts as a sampling area. The minimum range is defined by two key features: the number of species present and the area covered, with the species list representing the flora encountered and the area serving as a measure of the adequacy of this list. Therefore, a floristic sample of a specific size should correspond to the minimum range flora and can be used as a standard for comparing and evaluating the floral structure of the region (Brauneder et al. 2018).

While there haven't been specific studies on the urban flora of Bukhara, previous research has discussed the plant species in the surrounding areas (Esanov 2016; Esanov, Usmanov 2018; Esanov, Sharipova 2020; Verkhozina et al. 2022). These studies have emphasized the presence of non-native species thriving in natural conditions as part of the urban flora, along with their establishment, naturalization, and invasive tendencies. These species play a significant role in enhancing the biodiversity of the city's urban flora. Presently, ongoing research on the urban flora of Bukhara aims to assess how global climate change impacts urban flora diversity, utilizing the floristic systematic grid method.

This study seeks to explore the diversity of trees, shrubs, and grasses in urban settings through field observations and existing literature, using Bukhara city in Uzbekistan as a focal point for investigation.

Materials and methods

In the Bukhara oblast, which covers an area of 143 km², we encounter a distinctly continental, desert climate marked by severe winters and hot, arid summers. With January temperatures averaging around -2 C and July temperatures soaring above 40 C, the region receives an annual precipitation of 90–150 mm, predominantly in the form of rainfall, placing it squarely within the arid zone. The Bukhara oasis, influenced significantly by desert winds due to its proximity to the desert (Gafarova, Gulamov 2021), boasts an impressive array of 476 plant species spanning 294 genera and 62 families (Esanov 2016).

Our research delved into the floristic diversity of Bukhara city through a systematic algorithm:

The city was partitioned into uniform minimum habitats. These minimum habitats, selected based on urban landscape characteristics, served as study areas. Comprehensive plant biodiversity surveys were conducted within each designated minimum habitat. The findings were collated using appropriate statistical techniques across all chosen sites within the city. We examined various urban landscape types, including garden and park areas, low-rise areas, high-rise areas, and factory areas, each with distinct features influencing plant diversity. To capture the essential traits of the flora, we employed the minimum areal method, focusing on five selected sample plots within Bukhara city, aided by data from various sources such as the Bukhara city cadastre map (Gafarova, Gulamov 2021), the Bukhara Department of Urban Amenities, and research data (Esanov 2016; Esanov, Sharipova 2020; Verkhozina et al. 2022).

Our assessment encompassed nine sample areas scattered across different city sectors to ensure a comprehensive representation of urban flora (Fig. 1), namely northern (Gijduvan Street), southern (Navoi Avenue and Piridastgir Street), western (Khavzi Bodom Street), eastern (B. Naqshband Street), and central parts (I. Muminov Street, Mustakillik Street, and M. Iqbol Street). This selection aimed to ensure maximum representativeness of urban flora. Throughout the study, we conducted detailed descriptions of green spaces along roads, near houses, in the central city Samonid recreation park, and at the "Ko’hna va boqiy Buxoro" recreation center. Additionally, we determined morphometric indices of trunk and crown, as well as the vital state, for each woody plant. Across the city, we observed 434 trees in the western part, 1145 trees in the eastern part, 658 trees in the central part, 468 trees in the southern part, and 1203 trees in the northern part. Detailed floristic descriptions and morphometric analyses were conducted in green spaces along roads, residential areas, city parks, and recreation centers, with 2–5 sample plots of 1000 m2 established at each site during fieldwork.

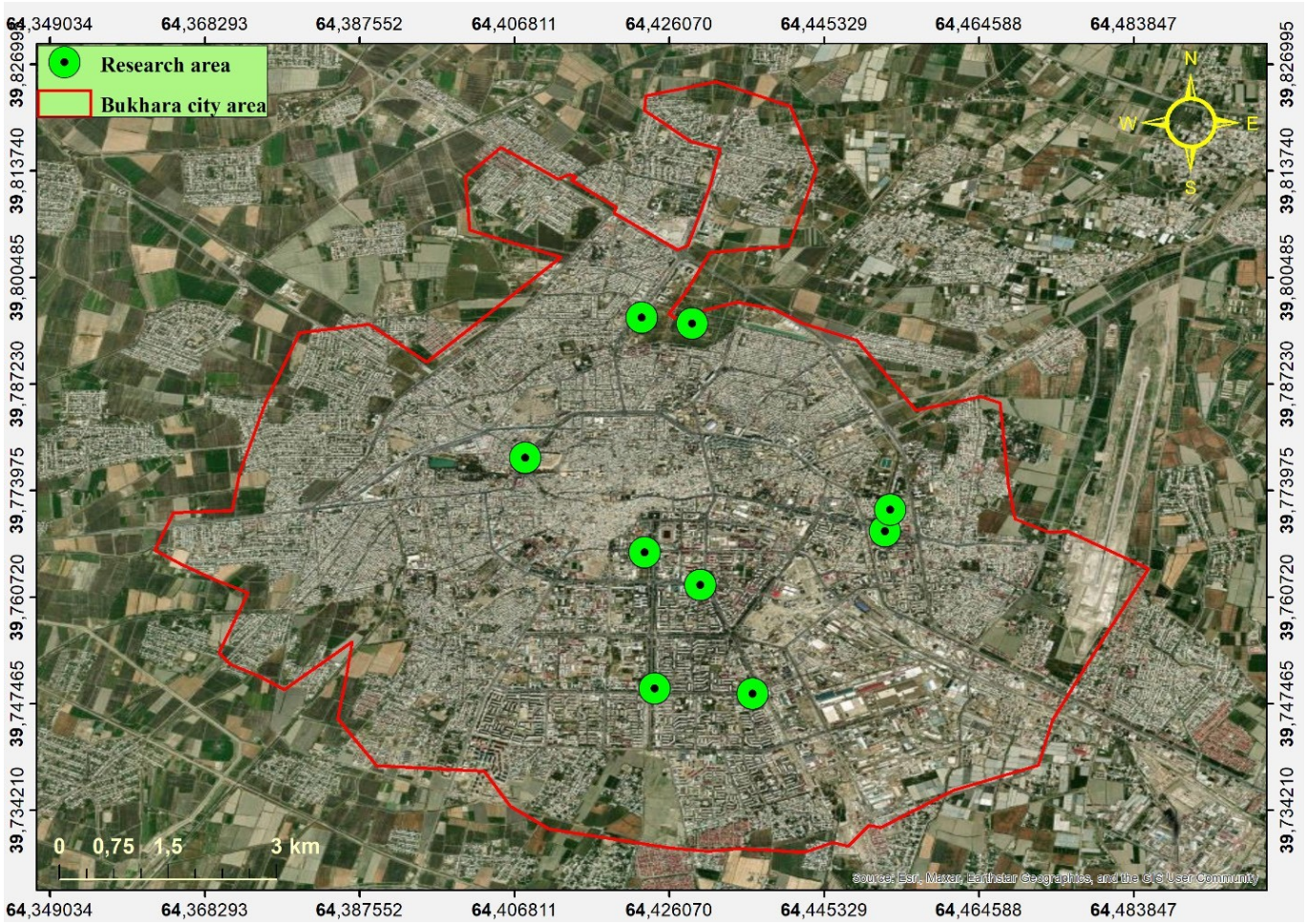

Figure 1. *Map of the Bukhara area. Observation sites are marked in green color.*

We meticulously cataloged 44 sites, identifying species with diverse life forms and assessing morphometric indices of woody plants. A thorough examination of trees in various city sections revealed varying tree populations, with a focus on species and life forms drawn from authoritative botanical resources and nomenclature systems (Flora of Uzbekistan 1941-1962; 2016; 2017; 2019; Central Asian Plant Identifier 1968–1993). In our quest to identify plant species and life forms, we consulted a range of botanical references and electronic databases to enhance our understanding of adventive species and enrich the study of Bukhara's urban flora (Christenhusz et al. 2011; APG IV 2016; Plants Names Index 2020; POWO (2023). Additionally, we utilized electronic resources such as the IUCN Global Invasive Species Database (2014), Global Invasive Species Database, and Invasive Species Compendium to identify adventive species.

Result

We registered that urban vegetation comprises 42 species of trees, 21 species of shrubs, and 70 species of herbaceous plants. We anticipate that these numbers will continue to rise in the future. The density of urban phytocenoses in the surveyed areas ranges from 40 to 55 species per 1000 m^2, encompassing 21–28 species of trees, 4–11 species of shrubs, and 14–28 species of herbaceous vegetation (Table 1).

City part	Species per 1000 m^2			
	Trees	Bushes	Herbs	Total
Northern	27	4	14	45
Southern	19	6	16	41

Western	28	8	21	57
Eastern	26	11	28	65
Central	21	6	18	45

Table 1. *Density of urban vegetation in Bukhara*

In the last decade, Bukhara city has seen the introduction of 22 tree species and 9 shrub species, as reported by the Bukhara Department of Urban Amenities (refer to Tables 4 and 5 for details).

The majority of these introduced species, entering the city through natural means, have become naturalized and are now considered invasive, like *Amaranthus viridis* L., *Erigeron bonariensis* L., *Symphyotrichum graminifolium* (Spreng.) G.L.Nesom., and *Chenopodium ficifolium* Sm. (Esanov 2016; Esanov, Sharipova 2020; Verkhozina et al. 2022). These species have been observed in various urban biotopes such as roads, ditches, flower beds, alleys, lawns, cultivated fields, and other locations.

The influx of alien species naturally entering Bukhara city is on the rise. For instance, according to Esanov (2023), *Scandix australis subsp. grandiflora* (L.) Thell. was initially identified in Bukhara in 2022, and its introduction continues due to anthropogenic influences. Additionally, we have determined the taxonomic composition of Bukhara's typical flora (refer to Table 2 for details).

As we studied the diversity of Bukhara's flora, we also identified the composition of introduced species (Table 3).

Family	Species	Trees	Bushes	Herbs
Equisetaceae Rich. ex DC.	1	-	-	1
Araceae Juss.	1	-	-	1
Potamogetonaceae	1	-	-	1
Typhaceae Juss.	1	-	-	1
Cyperaceae Juss.	4	-	-	4
Poaceae Barnhart	34	-	-	34
Ceratophyllaceae S. F. Gray	1	-	-	1
Papaveraceae Juss.	4	-	-	4
Ranunculaceae Juss.	5	-	-	5
Haloragaceae R. Br.	1	-	-	1
Zygophyllaceae R. Br.	2	-	-	2
Fabaceae Lindl.	26	-	2	24
Rosaceae Juss.	4	-	2	2
Elaeagnaceae Juss.	1	1	-	-
Urticaceae Juss.	1	-	-	1
Oxalidaceae R.Br.	1	-	-	1
Salicaceae Mirb.	1	1	-	-
Euphorbiaceae Juss.	2	-	-	2
Linaceae DC. ex Perleb	1	-	-	1
Geraniaceae Juss.	2	-	-	2
Nitrariaceae Lindl.	1	-	-	1
Malvaceae Juss.	6	-	-	6
Capparaceae Juss.	1	-	-	1
Brassicaceae Burnett	24	-	-	24
Frankeniaceae Desv.	1	-	-	1
Tamaricaceae Link	1	-	1	-
Plumbaginaceae Juss.	1	-	-	1

Polygonaceae Juss.	6	-	-	6
Caryophyllaceae Juss.	7	-	-	7
Amaranthaceae Juss.	34	-	2	32
Portulacaceae Juss.	1	-	-	1
Rubiaceae Juss.	4	-	-	4
Apocynaceae Juss.	2	-	-	2
Boraginaceae Juss.	6	-	-	6
Convolvulaceae Juss.	7	-	-	7
Solanaceae Juss.	4	-	1	3
Plantaginaceae Juss.	7	-	-	7
Verbenaceae J. St.-Hil.	1	-	-	1
Lamiaceae Martinov	3	-	-	3
Mazaceae Reveal.	1	-	-	1
Asteraceae Bercht. & J.Presl	37	-	-	37
Apiaceae Lindl.	6	-	-	6
Total	255	2	8	245

Table 2. *Natural flora of Bukhara*

Species	Trees	Bushes	Herbs
Acer negundo L.	+		
Acer platanoides L.	+		
Aesculus hippocastanum L.	+		
Ailanthus altissima (Mill.) Swingle	+		
Albizia julibrissin Durazz.	+		
Catalpa bignonioides Walter	+		
Corylus colurna L.	+		
Cupressus arizonica Greene	+		
Cydonia oblonga Mill.	+		
Fagus orientalis Lipsky	+		
Fraxinus lanceolata Borkh.	+		
Gleditsia triacanthos L.	+		
Juglans regia L.	+		
Juniperus virginiana L.	+		
Maclura pomifera (Raf.) C.K. Schneid.	+		
Mahonia × *wagneri* (Jouin) Rehder	+		
Malus domestica Borkh.	+		
Morus alba L.	+		
Morus nigra L.	+		
Morus rubra L.	+		
Paulownia tomentosa (Thunb.) Steud.	+		
Pinus brutia var. *eldarica* (Medw.) Silba	+		
Pinus nigra J.F. Arnold	+		
Pinus nigra subsp. *pallasiana* (Lamb.) Holmboe	+		
Pinus sylvestris L.	+		
Platanus orientalis L.	+		
Platycladus orientalis (L.) Franco	+		
Populus alba L.	+		

Prunus cerasus L.	+		
Prunus avium L.	+		
Prunus armeníaca L.	+		
Prunus domestica L.	+		
Prunus persica (L.) Batsch	+		
Prunus serrulata Lindl.	+		
Prunus communis L.	+		
Quercus robur L.	+		
Robinia pseudoacacia L.	+		
Styphnolobium japonicum (L.) Schott	+		
Thuja occidentalis L.	+		
Tilia cordata Mill.	+		
Tilia europaea L.	+		
Ulmus parvifolia L.	+		
Ulmus densa Litv.	+		
Amorpha fruticosa L.		+	
Berberis thunbergii DC.		+	
Buddleja davidii Franch		+	
Catharanthus roseus (L.) G. Don		+	
Caesalpinia gilliesii (Wall. ex Hook.) D. Dietr.		+	
Chaenomeles japonica (Thunb.) Lindl. ex Spach		+	
Euonymus japonicus Thunb.		+	
Ficus carica L.		+	
Hibiscus syriacus L.		+	
Jacobaea maritima (L.) Pelser ex Meijden		+	
Kochia scoparia var. *trichophylla* (Hort. ex Voss) L.H. Bailey		+	
Ligustrum vulgare L.		+	
Lonicera japonica Thunb.		+	
Mahonia aquifolium (Pursh) Nutt.		+	
Parthenocissus quinquefolia (L.) Planch		+	
Punica granatum L.		+	
Ribes nigrum L.		+	
Ricinus communis L.		+	
Rosa chinensis Jacq.		+	
Spartium junceum L.		+	
Spiraea × *vanhouttei* (Briot) Carriere		+	
Syringa vulgaris L.		+	
Yucca filamentosa L.		+	
Vitex agnus-castus L.		+	
Datura innoxia Mill.			+
Mirabilis jalapa L.			+
Helianthus annuus L.			+
Cucurbita pepo L.			+
Phaseolus vulgaris L.			+
Zínnia elegans Jacq.			+

Heliopsis helianthoides (L.) Sweet			+
Aster amellus L.			+
Tagetes patula L.			+
Canna ×generalis L.H. Bailey & E.Z. Bailey			+
Portulaca grandiflora Hook.			+
Symphyotrichum novi-belgii (L.) G.L. Nesom			
Total	43	24	12

Table 3. *Introduced plant species of Bukhara*

The study conducted in Bukhara city revealed quantitative data related to the composition and density of urban vegetation. The research identified 42 species of trees, 21 species of shrubs, and 70 species of herbaceous plants in the urban areas. The density of urban phytocenoses ranged from 40 to 55 species per 1000 m^2, with variations across different city sectors. For instance, the northern part of the city had 27 tree species, 4 shrub species, and 14 herb species per 1000 m^2, totaling 45 species. In comparison, the western part had the highest density with 28 tree species, 8 shrub species, and 21 herb species per 1000 m^2, totaling 57 species.

The introduction of adventive plants from abroad led to the naturalization of 22 tree species and 9 shrub species in the last decade. The influx of alien species, such as Amaranthus viridis and Erigeron bonariensis, has contributed to the increase in the number of introduced species in the city. The taxonomic composition of Bukhara's flora included 255 species from 34 families, with a dominance of herbaceous plants.

Discussion

In recent years, the floristic biodiversity of Bukhara city has experienced a surge, attributed to the introduction of adventive plants from abroad (Esanov, Sharipova 2020). This influx has led to a noticeable increase in the number of ornamental trees, shrubs, and grasses within the study area. Notably, the natural introduction of herbaceous plants into the urban flora, and their rapid spread as invasive species, has significantly impacted biodiversity (Pyšek 1998; Lososová et al. 2012).

According to our findings from the research carried out in 2022 (Table 2), the botanical landscape in Bukhara boasts a rich tapestry of 255 species belonging to 42 families of naturally occurring higher plants. Among these, there are 245 herbaceous species, 2 tree species, and 8 shrub species. This botanical composition mirrors the characteristic profile of desert flora. The remarkable presence of tree and shrub species within the urban setting can be attributed to the introduction of exotic species, particularly evident in densely populated regions characterized by high-rise structures and along major thoroughfares.

The number of ornamental species introduced into the urban flora of Bukhara is steadily increasing as part of the city improvement program (Table 4). However, their successful integration is hindered by the ongoing changes in urban structure and soil and climatic conditions, which reduce the likelihood of survival for nonnative species. Consequently, the count of introduced species continues to rise.

Our findings (Table 3) reveal that the introduced vegetation comprises 79 species from 34 families. Notably, ornamental trees (43 species, Table 4) and shrubs (24 species, Table 5) dominate, indicating the successful acclimatization of these species despite the arid conditions. We also determined the density of vegetation in the study area (Table 6).

The influx of ornamental species into the urban environment of Bukhara is on a steady incline as

part of the city's ongoing beautification efforts, as indicated in Table 4. However, the seamless integration of these species is impeded by the persistent transformations in urban infrastructure, soil composition, and climatic variations, posing challenges to the survival prospects of non-indigenous flora. Consequently, the tally of introduced species continues to escalate.

Our analysis, detailed in Table 3, underscores that the introduced greenery encompasses a total of 79 species spanning 34 families. Noteworthy is the prevalence of ornamental trees, amounting to 43 species (refer to Table 4), and shrubs, totaling 24 species (refer to Table 5), underscoring their successful adaptation to the harsh arid environment. Furthermore, we have quantified the vegetation density within the research area, as elucidated in Table 6.

The study on urban floristic diversity in Bukhara city revealed significant findings regarding the composition and density of vegetation in the urban areas. The research identified 42 species of trees, 21 species of shrubs, and 70 species of herbaceous plants, with a density ranging from 40 to 55 species per 1000 m^2 across different city sectors. The introduction of adventive plants from abroad has led to a surge in the number of ornamental trees, shrubs, and grasses in the city, with 22 tree species and 9 shrub species introduced in the last decade.

The influx of alien species, such as *Amaranthus viridis* and *Erigeron bonariensis*, has been observed in various urban biotopes, indicating their successful naturalization and invasive tendencies. The taxonomic composition of Bukhara's typical flora was also determined, highlighting the presence of 255 species from 34 families, with a dominance of herbaceous plants. The study further identified 79 introduced plant species, with ornamental trees and shrubs being the most prevalent.

No	Species	According to the Department of Urban Amenities data (2016–2020)	According to authors data (2009–2023)
1	*Acer negundo* L.	-	+
2	*Acer platanoides* L.	+	-
3	*Aesculus hippocastanum* L.	+	+
4	*Ailanthus altissima* (Mill.) Swingle	-	+
5	*Albizia julibrissin* Durazz.	-	+
6	*Catalpa bignonioides* Walter	+	+
7	*Corylus colurna* L.	-	+
8	*Cupressus arizonica* Greene	-	+
9	*Cydonia oblonga* Mill.	-	+
10	*Elaeagnus angustifólia* L.	-	+
11	*Fagus orientalis* Lipsky	-	+
12	*Fraxinus lanceolata* Borkh.	-	+
13	*Gleditsia triacanthos* L.	+	+
14	*Juglans regia* L.	+	+
15	*Juniperus virginiana* L.	+	+
16	*Maclura pomifer*a (Raf) C.K. Schneid	+	+
17	*Mahonia* × *wagneri* (Jouin) Rehder	-	+
18	*Malus domestica* Borkh.	-	+
19	*Morus alba* L.	-	+
20	*Morus nigra* L.	-	+
21	*Morus rubra* L.	-	+
22	*Paulownia tomentosa* (Thunb.) Steud.	+	-
23	*Pinus brutia* var. *eldarica* (Medw.) Silba	+	+

24	*Pinus nigra* J.F. Arnold	+	+
25	*Pinus nigra* subsp. *pallasiana* (Lamb.) Holmboe	+	+
26	*Pinus sylvestris* L.	+	+
27	*Platanus orientalis* L.	-	+
28	*Platycladus orientalis* (L.) Franco	+	+
29	*Populus alba* L.	-	+
30	*Prunus avium* L.	-	+
31	*Prunus armeníaca* L.	-	+
32	*Prunus cerasus* L.	+	+
33	*Prunus domestica* L.	-	+
34	*Prunus persica* (L.) Batsch	-	+
35	*Prunus serrulata* Lindl.	+	-
36	*Prunus communis* L.	-	+
37	*Quercus robur* L.	+	+
38	*Robinia pseudoacacia* L.	+	+
39	*Salix alba* L.	-	+
40	*Styphnolobium japonicum* (L.) Schott	+	+
41	*Thuja occidentalis* L.	+	+
42	*Tilia cordata* Mill.	+	+
43	*Tilia europaea* L.	-	+
44	*Ulmus parvifolia* L.	+	+
45	*Ulmus densa* Litv.	+	+
Total		22	42

Table 4. *Comparative analysis of woody plants of Bukhara city for 2009–2023*

No	Species	According to the Department of Urban Amenities data (2016–2020)	According to authors data (2009–2023)
1	*Amorpha fruticosa* L.	+	-
2	*Berberis thunbergii* DC.	+	-
3	*Buddleja davidii* Franch.	+	-
4	*Catharanthus roseus* (L.) G.Don	-	+
5	*Caesalpinia gilliesii* (Wall. Ex Hook.) D.Dietr.	+	+
6	*Chaenomeles japonica* Thunb.	+	-
7	*Euonymus japonicus* Thunb.	+	+
8	*Ficus carica* L.	-	+
9	*Hibiscus syriacus* L.	+	-
10	*Jacobaea maritima* (L.) Pelser & Meijden	-	+
11	*Kochia* var. *trichophylla* (Hort. ex Voss) L.H. Bailey	-	+
12	*Ligustrum vulgare* L.	-	+
13	*Lonicera japonica* Thunb.	-	+
14	*Mahonia aquifolium* (Pursh) Nutt.	-	+
15	*Parthenocissus quinquefolia* (L.) Planch	-	+
16	*Peganum harmala* L.	-	+
17	*Ribes nigrum* L.	-	+
18	*Ricinus communis* L.	-	+
19	*Rosa chinensis* Jacq.	-	+

20	*Rosa canina* L.	-	+
21	*Spartium junceum* L.	-	+
22	*Spiraea* × *vanhouttei* (Briot) Carriere	+	-
23	*Syringa vulgaris* L.	+	+
24	*Tamarix ramosissima* Lebed.	-	+
25	*Vitex agnus-castus* L.	-	+
26	*Vitis vinifera* L.	-	+
27	*Yucca filamentosa* L.	-	+
Total		9	21

Table 5. *Comparative analysis of shrub vegetation in Bukhara city for 2009–2023*

City part	Trees	% from 42 species	Shrubs	% from 21 species	Herbs	% from 70 species
Northern	27	64.3	4	19.0	14	20.0
Southern	19	45.2	6	28.6	16	22.09
Western	28	66.7	8	38.1	21	30.0
Eastern	26	61.9	11	52.3	28	40.0
Central	21	50.0	6	28.6	18	25.7

Table 6. *Vegetation density in different city parts*

The density of urban vegetation in Bukhara city was estimated to be approximately 49.6 species per 1000 m^2 on average, with varying distributions of trees, shrubs, and herbaceous plants across different city parts. The uneven distribution of vegetation types was attributed to changes in the city layout and urban structure. The research underscores the importance of green spaces in the city and the ongoing beautification efforts that contribute to the introduction and successful acclimatization of ornamental species in the urban environment.

The qualitative data gathered during the research in Bukhara city revealed key patterns and trends related to the urban flora. One significant trend observed was the successful acclimatization of introduced ornamental trees and shrubs despite the arid conditions of the region. Another pattern identified was the uneven distribution of vegetation types across different city parts, influenced by changes in urban layout and structure.

We believe that the uneven distribution of vegetation types in urban areas can be attributed to the frequent changes in the city layout. On average, there are 19.96 to 27.64 species of trees, 3.92 to 8.88 species of shrubs, and 15.32 to 23.48 species of herbaceous vegetation per 1000 m^2 of the city area (see Table 6). With the total vegetation cover of Bukhara city estimated at 2950.1 m^2 10^3 (Gafarova, Gulamov 2021), the density of urban vegetation is approximately 49.6 species per 1000 m^2 on average.

The findings of the study align with existing theories on urban biodiversity, ecosystem services, and the impact of human activities on plant communities. The successful acclimatization of introduced species supports the theory of species adaptation to urban environments. The study's results align with previous research on urban vegetation diversity, especially in arid regions. The increase in introduced species and their impact on urban flora corroborates findings from similar studies. Discrepancies in species composition and density may be attributed to local environmental factors, urban development patterns, and the introduction of new species over time.

In summary, the study's key findings underscore the importance of urban vegetation for biodiversity, ecosystem services, and community well-being in Bukhara city. While the research contributes valuable insights, future studies should address long-term monitoring, conservation strategies, and the ecological impacts of urbanization on plant diversity. The study's limitations should be considered when interpreting the results, and the implications for future research and urban planning practices are significant for promoting sustainable urban environments in arid

regions.

Overall, our research on Bukhara's urban vegetation provides valuable insights into the importance of green spaces in the city and the need for sustainable management and conservation strategies. Future research should focus on monitoring changes in urban vegetation over time, assessing the impact of urbanization on plant diversity, and exploring innovative approaches to enhance the ecosystem services provided by green spaces in Bukhara.

Conclusion

Bukhara city's flora comprises 334 species of higher plants, including 257 species of herbaceous plants, 32 species of shrubs, and 45 species of trees, which is characteristic of arid zones. The average density of urban vegetation in Bukhara city is 50.60 species per 1000 m^2, with 31.5% being trees (20–24 species), 15.8% shrubs (5–9 species), and 52.6% herbaceous plants (15–24 species).

In conclusion, the study on urban floristic diversity in Bukhara city provides valuable insights into the changing landscape of urban vegetation in the region. The introduction of adventive plants has significantly impacted the composition and density of vegetation, with a notable increase in ornamental species. The successful integration of these species, despite the arid conditions, highlights the resilience and adaptability of urban flora in Bukhara.

Moving forward, it is essential to monitor changes in urban vegetation over time, assess the impact of urbanization on plant diversity, and implement sustainable management and conservation strategies to preserve and enhance biodiversity in Bukhara. By understanding the dynamics of urban flora and the ecosystem services provided by green spaces, policymakers and urban planners can work towards creating a more sustainable and resilient urban environment for the residents of Bukhara.

References

A Global Standard for the Identification of Key Biodiversity Areas (2016) Version 1.0. IUCN, Gland, Switzerland, 37 pp.

Alves B (2024) Biodiversity loss – statistics & facts. Available from: https://www.statista.com/topics/11263/biodiversity-loss/

APG IV (2016) The Angiosperm Phylogeny Group. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants. Botanical Journal of the Linnean Society 181 (1): 1–20. https://doi.org/10.1111/boj.12385

Brauneder KM, Montes C, Blyth S, Bennun L, Butchart SHM, Hoffmann M, Burgess ND, Cuttelod A, Jones MI, Kapos V, Pilgrim J, Tolley MJ, Underwood EC, Weatherdon LV, Brooks SE (2018) Global screening for critical habitat in the terrestrial realm. PloS One 13(3): e0193102. https://doi.org/10.1371/journal.pone.0193102

Ceplová N, Kalusová V, Lososová Z (2017a) Effects of settlement size, urban heat is land and habitat type on urban plant biodiversity. Landscape and Urban Planning 159: 15–22. https://doi/org/10.1016/j.landurbplan.2016.11.004

Čeplová N, Kalusová V, Lososová Z (2017b) Does the size of settlement matter? Effects of urban heat island, settlement size and habitat type on urban plant biodiversity. Landscape and Urban Planning 159: 15–22. https://doi.org/10.1016/j.landurbplan.2016.11.004

Christenhusz MJ, Reveal JL, Farjon A, Gardner MF, Mill RR, Chase MW (2011) A linear sequence of

extant families and genera of lycophytes and ferns. Phytotaxa 19: 7–54. https://doi.org/10.11646/phytotaxa.19.1.2

Conspectus Florae Asiae Mediae (1963–2015) In 11 volumes. Fan Publishers, Tashkent. [In Russian]

Esanov HK (2016) New Plant Species in the Flora of Bukhara Oasis. Turczaninowia 19: 77–81. https://doi.org/10.14258/turczaninowia.19.2.10[In Russian]

Esanov HK, Usmonov MX (2018) Two Alien Species of Asteraceae New to Uzbekistan (Bukhara Oasis). Turczaninowia 21: 175–180. https://doi.org/10.14258/turczaninowia.21.4.18

Esanov HK, Sharipova VK (2020) Addition to the flora of Bukhara region (Uzbekistan). Turczaninowia 23(1): 126–128. https://doi.org/10.14258/turczaninowia.23.1.13 [In Russian]

Esanov HK (2021) High plant species distributed in and around Dengizkul, Bukhara Region. American Journal of Plant Sciences 12: 266–273. https://doi.org/10.4236/ajps.2021.122016

Esanov HK (2023) Flora of South-West Kyzylkum. PhD Thesis. Institute of Botany, Tashkent, 195 pp. [In Uzbek]

Flora of Uzbekistan (1941–1962) In 6 volumes. Academy of Sciences of the Uzbek SSR, Tashkent. [In Russian]

Flora of Uzbekistan (2016–2017) Volumes 1–2. Navruz, Tashkent. [In Russian] Flora of Uzbekistan (2019) Vol. 3. Manaviyat, Tashkent. [In Russian]

Gafarova SM, Gulamov MI (2021) Modern physical-geographical and environmental characteristics of the city of Bukhara. Universum: Chemistry and Biology 12(90). https://doi.org/10.32743/UniChem.2021.90.12.12566[In Russian]

Global Invasive Species Database (2023) Available from: http://issg.org/

Grapow L, Blasti C (1998) A comparison of the urban flora of different phytoclimatic regions in Italy. Global Ecology & Biogeography Letters 7: 367–378. https://doi.org/10.1046/j.1466-822x.1998.00304.x

Gulamov MI (2022) On the question of the mechanisms of structural changes in diversity. Danish Scientific Journal 65: 3–6. https://doi.org/10.5281/zenodo.7274464

International Plant Names Index (2020) Available from: http://www.ipni.org/

Invasive Species Compendium (2023) Available from: http://www.cabi.org/isc/

Jovanović S, Glišić M (2021) Research analysis on urban flora and vegetation in Southeast Europe. Acta Botanica Croatica 80(1): 74–81. https://doi.org/10.37427/botcro-2021-004

Kate W (2022) Six charts that show the state of biodiversity and nature loss – and how we can go nature positive. Available from: https://www.weforum.org/agenda/2022/10/nature-loss-biodiversity-wwf/

Klausnitzer B (1982) Grosstadteals Lebenstraumfür das mediterrane Faunenelement. Entomologische Nachrichten und Berichte 26: 49–57.

Klausnitzer B (1983) ZurInsektenfauna der Städte. Entomologische Nachrichten und Berichte 27:

49–59. https://doi.org/10.1007/BF00388077

Knapp S, Dinsmore L, Fissore C, Hobbie SE, Jakobsdottir I, Kattge J, King JY, Klotz S, Mc-Fadden JP, Cavender-Bares J (2012) Phylogenetic and functional characteristics of household yard floras and their changes along an urbanization gradient. Ecology 93: 83–98. https://doi.org/10.1890/11-0392.1

Lososová Z, Chytrý M, Tichý L, Danihelka J, Fajmon K, Hájek O, Kintrová K, Kühn I, Láníková D, Otýpková Z, Ăehořek V (2012) Native and alien floras in urban habitats: a comparison across 32 cities of central Europe. Global Ecology and Biogeography 21(5): 545–555. https://doi.org/10.1111/j.1466-8238.2011.00704.x

POWO. Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Available from: http://www.plantsoftheworldonline.org/(accessed 15.12.2023)

Prokhorov NB, Usmanova NR (2018) Phytocenotic diversity and ecological assessment of park vegetation in Kazan. Ecology and geography of plants and plant communities. Proceedings of the IV International Scientific Conference, Yekaterinburg, 760–764 p.

Pyšek P (1998) Alien and native species in Central European urban floras: a quantitative comparison. Journal of Biogeography 25(1): 155–163. https://doi.org/10.1046/j.1365-2699.1998.251177.x

Tretyakova AS, Baranova OG, Senator SA, Panasenko NN, Sutkin AV, Alikhadzhiev MKh (2021) Studies of urban flora in Russia: Current state and prospects. Turczaninowia 24(1): 125–144. https://doi.org/10.14258/TURCZANINOWIA.24.1.15

Tretyakova A, Veselkin DV, Senator SA, Golovanov YaM (2018) Factors of Richness of Urban Floras in the Ural-Volga Region. Russian Journal of Ecology 49(3): 201–208. https://doi.org/10.1134/S1067413618030098

Vähä-Piikkiö I, Kurtto A, Hahkala V (2004) Species number, historical elements and protection of threatened species in the flora of Helsinki, Finland. Landscape and Urban Planning 68(4): 357–370. https://doi.org/10.1016/S0169-2046(03)00149-X

Verkhozina AV, Anisimov AV, Beshko NYu, Biryukov RYu, Bondareva VV, Chernykh DV, Dorofeev NV, Dorofeyev VI, Ebel AL, Efremov AN, Erst AS, Esanov HK, Esina IG, Fateryga AV, Fateryga VV, Fomenko VA, Gamova NS, Gaziev AD, Glazunov VA, Grabovskaya-Borodina AE, Grigorenko VN, Jabborov AM, Kalmykova OG, Kapitonova OA, Kechaykin AA, Khapugin AA, Kholodov ON, Khoreva MG, Kin NO, Korolyuk AYu, Korolyuk EA, Korotkov YuN, Kosachev PA, Kozyr IV, Kulagina MA, Kulakova NV, Kuzmin IV, Lashchinskiy NN, Lazkov GA, Luferov AN, Dmitrii N. Malov DN, Marchuk EA, Murtazaliev RA, Olonova MV, Ovchinnikova SV, Ovchinnikov YuV, Pershin DK, Peskova IM, Plikina NV, Pyak AI, Pyak EA, Salokhin AV, Senator SA, Shaulo DN, Shmakov AI, Shumilov SV, Smirnov SV, Sorokin VA, Stepantsova NV, Svirin SA, Tajetdinova DM, Tsarenko NA, Vasjukov VM, Yena AV, Yepikhin DV, Yevseyenkov PE, Wang W, Zolotov DV, Zykova EYu, Murashko VV, Krivenko DA (2022) Findings to the flora of Russia and adjacent countries: New national and regional vascular plant records, 4. Botanica Pacifica. A Journal of Plant Science and Conservation 11(1): 129–157. https://doi.org/10.17581/bp.2022.11114

Vershinin VL (2014) Urban Ecology. Ekaterinburg Ural University Publishing House, Ekaterinburg, 10–11.