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Urban Cemeteries as Biodiversity Refuges: A Comparative Study of Plant Ecobiomorphs in Central Kazakhstan

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Abstract: Cemeteries are often overlooked in ecological studies, yet they represent unique urban microhabitats that contribute to the preservation of diverse plant species, including those adapted to various ecological niches. This study aimed to assess the species composition, ecological classifications, and abundance of vascular plants in the cemetery and surrounding areas to explore cemeteries' role in conserving plant ecobiomorph diversity in arid climates. This study identified 79 plant species from 23 families within the cemetery compared with 31 species from 11 families in the surrounding area. The plant community in the cemetery was dominated by mesophytes, suggesting favorable and stable conditions for plant growth, while xerophytes were more common in the surrounding areas, indicating harsher, drier conditions. The diversity of plant life forms, including perennial herbs, shrubs, and trees, was significantly higher within the cemetery, indicating a more complex and resilient ecosystem. Our study demonstrates that cemeteries act as vital refuges for plant biodiversity. They offer significantly higher species diversity and more complex ecosystem structures compared with the surrounding areas. These findings emphasize the critical role cemeteries play in urban biodiversity conservation, particularly in increasingly arid environments.

Keywords: mesophytes; xerophytes; arid climates; microhabitats; species diversity; microclimate; ecosystem resilience; anthropogenic pressure; steppe ecosystems; climate adaptation

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1. Introduction

Plant biodiversity is a crucial component of ecosystems, ensuring the resilience and productivity of natural communities. In recent decades, the urgency of biodiversity conservation has intensified due to the significant impacts of global warming on ecosystems worldwide [1–3]. Climate change, driven by anthropogenic activities such as fossil fuel combustion, deforestation, and agriculture, has become one of the most critical global challenges, releasing large amounts of greenhouse gases into the atmosphere [4,5]. This leads to increased global average temperatures, altered precipitation patterns, and more frequent and intense extreme weather events, exerting significant pressure on plant biodiversity [6,7].

One of the primary consequences of climate change is the shifting of climatic zones. As temperatures rise, many plant species are forced to migrate northward or to higher altitudes where conditions are more suitable for their survival [8]. This shift alters plant community compositions and disrupts ecological balance [9]. Additionally, climate change affects the seasonal cycles of plant development, including flowering, fruiting, and leaf shedding [10]. Accelerated spring processes may disrupt the synchronization between plants and their pollinators, leading to reduced reproductive success [11].

Climate change can also reduce the genetic diversity of plant populations. Under changing climatic conditions, many species face increased stress, resulting in population declines and loss of genetic variability [12–14]. Moreover, the impact of climate change on water regimes is particularly critical for plants. Droughts and floods are becoming more frequent and severe, causing stress and reducing the resilience of plants [15–17]. In arid regions, this may lead to habitat loss and a decline in biodiversity.

To mitigate the effects of climate change on plant biodiversity, comprehensive conservation strategies are being developed. These strategies include establishing protected natural areas like reserves, national parks, and biosphere reserves, which provide habitat protection and help preserve unique ecosystems and plant species [18,19]. Restoring degraded ecosystems and rehabilitating plant habitats are also crucial, and these include efforts like tree planting, restoring water systems, and sustainable land management practices [20,21].

In urban environments, beyond reserves and parks, there exists another significant reservoir of plant biodiversity—cemeteries. Cemeteries play a unique role in maintaining biodiversity, serving as natural oases within urbanized landscapes [22]. They are distinct ecosystems that differ from other areas in many ecological parameters, including soil composition, microclimate, and the flora and fauna they support [23]. These differences stem from specific conditions related to burials, architecture, and maintenance traditions.

The soil in cemeteries can vary greatly but is generally well-drained and sometimes slightly alkaline due to the presence of concrete and other burial materials [24,25]. This soil type supports plant species that thrive in less acidic conditions. Moreover, cemetery soil is often enriched with organic matter from decomposed bodies and plant residues, creating unique conditions that promote the growth of specific plant species [26]. The microclimate in cemeteries also plays a crucial role in their ecological characteristics. Cemeteries with dense tree and shrub cover create shaded areas, offering more stable humidity and temperature levels compared with open urban spaces [27]. These conditions favor the growth of shade-tolerant and moisture-loving plants that cannot compete in more exposed and arid environments.

Human activities in cemeteries are also distinct. Traditions of grave maintenance include regularly updating flowers, planting ornamental plants, and keeping the area clean, resulting in a landscape shaped by cultural practices [28]. While other urban green spaces are managed primarily for recreation, cemeteries focus on memorial functions. Consequently, cemeteries often host more ornamental and flowering plants, such as roses, lilies, and chrysanthemums, which are planted to adorn graves [29].

Abandoned cemeteries represent unique ecosystems where nature gradually reclaims once well-maintained areas. Over time, as human activity diminishes or ceases altogether, vegetation begins to thrive, altering the appearance and ecological state of these places [30]. The lack of human intervention also encourages the development of local flora, including rare and protected plant species. In minimally disturbed conditions, some plant species that faced competition in more urbanized and managed areas find suitable environments for growth and reproduction [31]. However, abandoned cemeteries can also become sites for the spread of invasive plant species, which can quickly overrun large areas due to little competition and lack of maintenance [32].

The floristic diversity of cemeteries is unique. Due to reduced human intervention and specific soil characteristics, rare and protected plant species can thrive in these areas [23]. Cemeteries, with their unique microhabitats, provide conditions that can influence plant morphology and contribute to diverse morphological adaptations. Changes in soil composition, microclimate, and human activities create a mosaic of environments that support a wide range of plant forms. Morphological characteristics, including both macroscopic features (e.g., leaf shape, plant height) and microscopic features (e.g., pollen structure), are essential for species identification and understanding ecological relationships [33]. This morphological diversity enhances ecological complexity and resilience, contributing to the conservation of urban biodiversity.

Understanding the morphological features of plants is especially important in arid climates, where environmental stresses can lead to distinctive adaptations. By studying these morphological characteristics, we can gain insight into how plants cope with harsh conditions and how cemeteries serve as refuges for diverse plant life.

While forests and meadows may experience a decline in plant diversity due to agricultural and industrial activities, cemeteries often preserve patches with rich biodiversity [34]. Despite their primary function, cemeteries remain underexplored in terms of their ecological and biological value. Studying plant biodiversity in cemeteries not only enhances our understanding of ecological processes but also has practical implications. The findings from such research can be used to develop strategies for biodiversity conservation in urban areas, improve the ecological resilience of urban landscapes, and create more favorable living conditions for people [35,36].

In this context, the objective of our study was to assess the species composition, ecological classifications, and morphological diversity of vascular plants in a Central Kazakhstan cemetery and its adjacent areas. By comparing the biodiversity within the cemetery to that of the surrounding landscape, we aimed to understand the role of cemeteries in conserving plant biodiversity in arid urban environments. We hypothesized that the cemetery, due to its unique microhabitats and reduced anthropogenic pressure, exhibits higher plant species diversity and different ecological characteristics compared with the surrounding areas.

2. Materials and Methods

2.1. Study Area

2.1.1. Location and Environmental Conditions

The experimental fieldwork was conducted from mid-May to mid-June 2024. The primary method used in the field studies was a transect survey. Tikhonovskoye cemetery, located at coordinates 49°55′44″ N 73°4′56″ E, is situated in the central part of Kazakhstan, near the city of Karaganda. The study area was conditionally divided into two territories with a total area of 1,291,327 m^2. Territory 1 refers to the area surrounding the cemetery, extending 3–10 m from the cemetery's fence. Territory 2 encompasses the Tikhonovskoye cemetery itself, with an area of 766,590 m^2 (Figure 1).

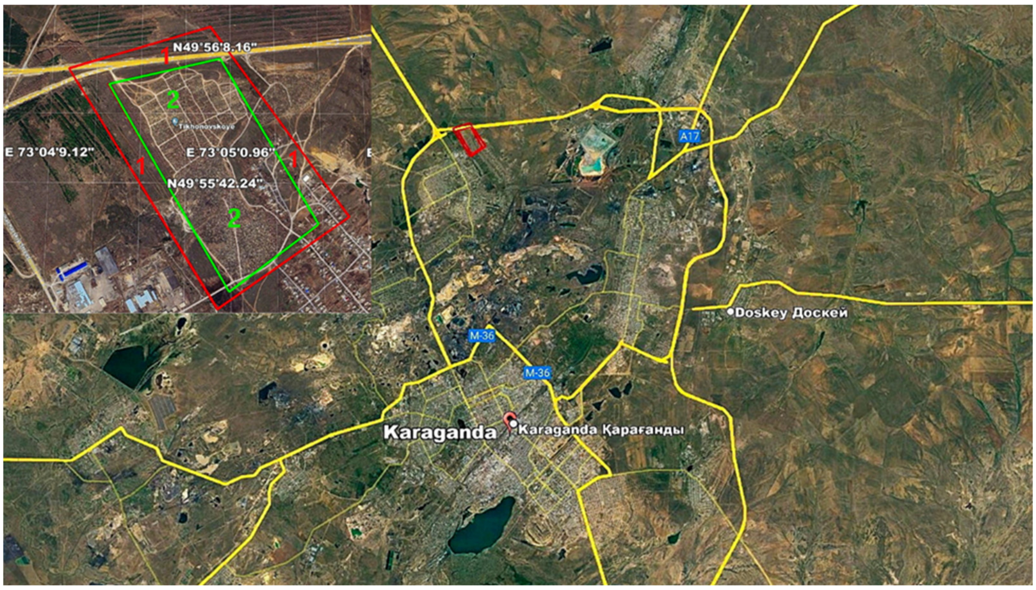

Figure 1. Study Area. 1—surroundings of Tikhonovskoye Cemetery, 2—Tikhonovskoye Cemetery (Karaganda, Central Kazakhstan).

This area possesses unique geographical features, characterized by steppe and semi-desert landscapes, forming part of the vast Kazakh Uplands. The climate in this region is continental, marked by cold winters and hot, dry summers. Winter temperatures can drop below −25 °C, while summer temperatures can rise above +30 °C. Precipitation is scarce, primarily occurring in spring and autumn, leading to predominantly arid conditions throughout the year.

The flora in this region is predominantly steppe vegetation, with grasses such as various species of feather grass being the dominant type. These plants are well-adapted to arid conditions, often having small or deep-set leaves that reduce evaporation. Additionally, xerophytic species like wormwood, which are adapted to survive in water-scarce environments, are commonly found.

Water resources in this area are limited. The primary sources of water are small rivers and temporary streams, replenished during the spring thaw. These water bodies often dry up completely during the hot summer, presenting significant challenges for water supply to the local population, as well as to the flora and fauna.

The soils in the area mostly consist of chestnut and solonetzic types, characterized by low fertility and a high content of mineral salts. Consequently, agricultural use of the land is limited, although drought-resistant crops can be cultivated in areas where water is available [37].

2.1.2. Field Sampling Methods

To ensure comprehensive coverage of the study areas, we employed a systematic transect sampling method. In Territory 1 (the surrounding area), five transects were established perpendicular to the cemetery fence at regular intervals to capture the variability in vegetation near the boundary. In Territory 2 (within the cemetery), ten transects were laid out in a grid pattern, running north-south and east-west, to intersect different habitat types and management zones. Each transect measured 100 m in length and 2 m in width. This width was chosen to balance the need for detailed observation with practical constraints on time and resources. Transects were strategically placed to provide representative samples of different microhabitats, such as shaded areas under trees, open grassy plots, and areas near monuments. Locations were determined using a random stratified approach, ensuring that all habitat types within the territories were proportionally represented. Along each transect, we conducted continuous sampling, recording all vascular plant species encountered. For each species, we noted its abundance using Drude's scale and collected specimens for further identification. This method allowed us to assess species composition and abundance systematically across different habitats within both territories.

The transect method allowed for systematic coverage and was effective in detecting variations in species composition and abundance across different habitats. This approach aligns with similar studies in arid environments, facilitating comparison and validation of our findings [38]. By employing this method, we aimed to obtain a comprehensive understanding of the plant biodiversity within and around Tikhonovskoye Cemetery.

2.1.3. Historical Context

Tikhonovskoye Cemetery, one of the oldest in Karaganda, was established in the mid-20th century. Named after Father Tikhon, a priest who played a key role during the Soviet and post-Soviet eras—a time marked by the revival of religious life in the region—the cemetery reflects the diverse ethnic composition of Karaganda's population. It has served as a burial ground for people of various nationalities and faiths, including Orthodox Christians, Catholics, Muslims, and representatives of other religions, making it a symbol of the city's cultural diversity.

Today, Tikhonovskoye Cemetery is a closed cemetery that undergoes moderate maintenance but faces challenges such as littering, livestock grazing, and occasional vegetation mowing. The cemetery is in need of care and preservation, with many old graves requiring restoration.

2.1.4. Description of Tikhonovskoye Cemetery

Tikhonovskoye Cemetery is one of the oldest in Karaganda. The physical characteristics of Tikhonovskoye Cemetery are unique. The cemetery spans an area of 766,590 m^2 and features a grid-like layout with a network of pathways dividing it into sections. The terrain is relatively flat with slight undulations, which may influence drainage patterns and the microclimate. Within the cemetery, various monuments, tombstones, and mausoleums made of materials such as granite, marble, and concrete are present. These structures create diverse microhabitats by providing shade and affecting soil conditions. The soil composition in the cemetery consists of a mixture of chestnut and solonetzic types, altered by the addition of substances from decaying plant material and burial practices. The soil pH may be slightly alkaline due to the presence of concrete and other materials. The presence of vegetation and structures creates a microclimate with reduced temperature extremes and increased humidity compared with the surrounding steppe. Special areas under trees and monuments are maintained to preserve soil conditions. Management practices at the cemetery are characterized by its abandoned state, with maintenance carried out locally by relatives who perform cleaning and trimming of vegetation. Maintenance activities include mowing grass, pruning overgrown shrubs, and cleaning pathways. There is no strict vegetation management plan at the cemetery, allowing for natural succession and plant colonization. The absence of herbicides or pesticides promotes biodiversity. The historical context influencing biodiversity includes cultural traditions of planting ornamental and memorial plants around graves, which ensures species diversity. Some areas of the cemetery are less visited or abandoned, allowing for natural vegetation succession and the establishment of native species. The introduction of non-invasive species through planting and memorial offerings has increased plant species diversity [37].

2.2. Sample Identification

The assessment of plant ecobiomorphs was conducted using Bykov's methodology:

- Xerophytes: plants adapted to drought conditions and dry climates, characterized by deep roots, waxy leaf coatings, small or absent leaves, and thick stems for water storage;
- Mesophytes: plants that thrive in moderate conditions with average water availability, without specific adaptations for excess or deficiency of water;
- Xeromesophytes: plants capable of surviving in both moderately moist and dry conditions, adaptable to varying levels of water supply;
- Mesoxerophytes: plants that can endure short periods of drought but prefer higher moisture levels, with adaptations that are less pronounced than those of xerophytes [39,40].

The abundance of plant species in each plant community was determined using Drude's scale: Cop1—many, Cop2—slightly more, Cop3—very many, Sparsae, Sp—often, Solitaria, Sol—few, Un—very few [41].

Laboratory processing of the initial material was conducted in strict compliance with all requirements, and herbarium samples were stored in the herbarium collection of Karaganda Medical University, Department of Biomedicine [42,43]. To identify the collected materials, major floristic references covering Kazakhstan were used: Flora of Kazakhstan [44]. Plant names were provided according to the "Plants of the World Online" database (http://www.plantsoftheworldonline.org/ (accessed on 15 September 2024)).

3. Results

3.1. Species Composition of Vascular Plants in the Area Adjacent to Tikhonovskoye Cemetery (Territory 1)

The plant community in Territory 1, which includes the areas adjacent to the cemetery, represents a typical meadow-steppe ecosystem. The dominant species in this community are grasses, which are complemented by a wide variety of herbaceous plants from different families, such as Asteraceae, Fabaceae, and Brassicaceae. This variety of herbaceous plants significantly contributes to the biodiversity of the community (Figure 2).

In the area adjacent to Tikhonovskoye Cemetery (Territory 1), 31 species belonging to 11 families were recorded. The bioecological characteristics of these plants are presented in Table 1.

Figure 2. Plant biodiversity in the area surrounding Tikhonovskoye cemetery (Territory 1).

Table 1. Bioecological characteristics of plants growing in Territory 1.

Family	Plant Species	Ecobiomorph/Life Form	Abundance	Purpose
Asteraceae	*Cirsium arvense* (L.) Scop.	Mes/Per	Sp	weedy
	Cichorium intybus L.	Xer Mes/Per	Sp	medicinal, forage
	Tragopogon dubius Scop.	Xer Mes/An	Sol	medicinal, ornamental
	Taraxacum officinale F.H.Wigg.	Mes/Per	Cop1	medicinal, food plant
	Arctium tomentosum Mill.	Mes/Per	Sol	medicinal
	Silybum marianum (L.) Gaertn.	Mes/An	Sp	medicinal, ornamental
	Matricaria chamomilla L.	Mes/An	Sp	medicinal, honey plant
	Artemisia dracunculus L.	Xer Mes/Per	Sp	food plant, medicinal
	Artemisia austriaca Jacq.	Xer/Per	Cop1	medicinal
	Artemisia absinthium L.	Xer/Per	Sp	medicinal
	Achillea millefolium L.	Mes/Per	Sp	medicinal, ornamental
	Artemisia pauciflora Weber ex Stechmann	Xer/Per	Cop2	medicinal
Poaceae	*Agropyron cristatum* (L.) Gaertn.	Xer/Per	Cop3	forage, weedy
	Calamagrostis epigejos (L.) Roth	Mes/Per	Cop1	forage, weedy
	Poa pratensis L.	Mes/Per	Cop1	forage, ornamental
	Elytrigia intermedia (Host) Nevski	XerMes/Per	Cop2	forage, soil-improving
	Bromus inermis Leyss.	Mes/Per	Cop1	forage, soil-improving
	Agropyron repens (L.) P.Beauv.	MesXer/Per	Cop1	forage, weedy
	Hordeum jubatum L.	MesXer/Per	Cop2	forage, weedy
Polygonaceae	*Polygonum aviculare* L.	Xer/An	Cop1	medicinal, weedy
	Rumex longifolius DC.	Mes/Per	Sol	medicinal, weedy
Brassicaceae	*Barbarea vulgaris* W.T.Aiton	Mes/Per	Sol	medicinal, weedy
	Peltaria turkmena Lipsky	Xer/Per	Sol	medicinal
Fabaceae	*Medicago sativa* L.	Mes/Per	Sol	forage, soil-improving
	Melilotus officinalis (L.) Lam.	Xer/An	Sp	honey plant, medicinal
Euphorbiaceae	*Euphorbia esula* L.	Xer/Per	Cop1	weedy

Table 1. *Cont.*

Family	Plant Species	Ecobiomorph/Life Form	Abundance	Purpose
Convolvulaceae	*Convolvulus arvensis* L.	Xer/Per	Sol	weedy
Boraginaceae	*Nonea pulla* (L.) DC.	Mes/An	Cop1	weedy
Plantaginaceae	*Plantago major* L.	Mes/Per	Sol	medicinal
Lamiaceae	*Salvia tesquicola* Klokov & Pobed.	Xer/Per	Sol	medicinal, forage
Caryophyllaceae	*Gypsophila paniculata* L.	XerMes/Per	Sp	medicinal, forage

Note: Cop1—many, Cop2—slightly more, Cop3—very many, Sp—often, frequently, Sol—few; Xer—Xerophyt, Mes—Mesophyt, XerMes—Xeromesophyt, MesXer—Mesoxerophyt; per—perennial, an—annual.

The plant community in the area surrounding Tikhonovskoye Cemetery (Territory 1) is representative of a typical meadow-steppe ecosystem, with grasses forming the core of the community. A diverse range of herbaceous plants from various families, including Asteraceae, Fabaceae, and Brassicaceae, adds significant biodiversity to this community.

In this area, 31 plant species from 11 families were recorded. The most species-rich family is Asteraceae, which has 12 species. This is followed by Poaceae with seven species, Polygonaceae with two species, Brassicaceae with two species, and Fabaceae with two species. Each of the following families is represented by only one species: Euphorbiaceae, Convolvulaceae, Boraginaceae, Plantaginaceae, Lamiaceae, and Caryophyllaceae.

Regarding life forms, the area hosts 6 annual herb species and 25 perennial herb species, with no shrubs or trees observed in the vicinity of Tikhonovskoye Cemetery.

In terms of ecological types, 10 species are classified as xerophytes, five species as xeromesophytes, two species as mesoxerophytes, and 14 species as mesophytes.

The most abundant species in the Asteraceae family include *Artemisia austriaca* (abundance category Cop1), *Artemisia pauciflora* (Cop2), and *Taraxacum officinale* (Cop1). In the Poaceae family, the most abundant species are *Agropyron cristatum* (Cop3), *Calamagrostis epigeios* (Cop1), *Poa pratensis* (Cop1), *Elytrigia intermedia* (Cop2), *Bromus inermis* (Cop1), *Agropyron repens* (Cop1), and *Hordeum jubatum* (Cop2).

The Euphorbiaceae family includes one species, *Euphorbia esula*, with an abundance of Cop1. Similarly, the Boraginaceae family is represented by one species, *Nonea pulla*, with an abundance of Cop1. The Polygonaceae family also has one species, *Polygonum aviculare*, with an abundance of Cop1.

Among the plants found in this area, weeds and forage plants are predominant, both in terms of species count and abundance. For instance, the weed species include *Agropyron cristatum* (Cop3), *Calamagrostis epigeios* (Cop1), *Poa pratensis* (Cop1), *Elytrigia intermedia* (Cop2), *Bromus inermis* (Cop1), *Agropyron repens* (Cop1), *Hordeum jubatum* (Cop2), *Polygonum aviculare* (Cop1), *Euphorbia esula* (Cop1), *Nonea pulla* (Cop1), and *Taraxacum officinale* (Cop1). The forage plants include *Agropyron cristatum* (Cop3), *Calamagrostis epigeios* (Cop1), *Poa pratensis* (Cop1), *Elytrigia intermedia* (Cop2), *Bromus inermis* (Cop1), and *Agropyron repens* (Cop1).

Medicinal plants present in this area include *Polygonum aviculare* (Cop1), *Rumex longifolius* (Sol), *Barbarea vulgaris* (Sol), *Peltaria turkmena* (Sol), *Melilotus officinalis* (Sp), *Cichorium intybus* L. (Sp), *Tragopogon dubius* (Sol), *Taraxacum officinale* (Cop1), *Arctium tomentosum* (Sol), *Silybum marianum* (Sp), *Matricaria chamomilla* (Sp), *Artemisia dracunculus* (Sp), *Artemisia absinthium* (Sp), *Achillea millefolium* (Sp), *Artemisia pauciflora* (Cop2), and *Salvia tesquicola* (Sol).

Xerophytes are the most abundant ecological type in this group. Among them, the most abundant species are *Agropyron cristatum* (Cop3), *Euphorbia esula* (Cop1), *Artemisia austriaca* (Cop1), and *Artemisia pauciflora* (Cop2). The most abundant mesophytes include *Calamagrostis epigeios* (Cop1) and *Poa pratensis* (Cop1). Among the xeromesophytes, the most abundant species is *Elytrigia intermedia* (Cop2), and among the mesoxerophytes, the most abundant species are *Agropyron repens* (Cop1) and *Hordeum jubatum* (Cop2).

3.2. Plant Species and Their Bioecological Characteristics in the Cemetery Area (Territory 2)

The plant community in Territory 2 is a diverse and dense assemblage typical of abandoned cemeteries. Various plant families, such as Asteraceae, Fabaceae, Poaceae, and others, are well-represented here. The vegetation includes a dense cover of grasses and abundant herbaceous plants of varying heights. These plants range from short to tall species. Additionally, numerous flowering plants attract pollinators, which helps maintain biodiversity. Besides herbaceous plants, shrubs and isolated trees are present, creating additional micro-ecological niches and enhancing the structural complexity of the community. Despite anthropogenic impacts, such as tombstones and other structures, the plant community retains high biodiversity and structural complexity (Figure 3).

Figure 3. Plant biodiversity on the territory of Tikhonovsky cemetery (Territory 2).

On the territory of Tikhonovsky Cemetery (Territory 2), 79 plant species belonging to 23 families were recorded. The characteristics of these plants are presented in Table 2.

Table 2. Bioecological characteristics of plants on Territory 2 (Tikhonovsky Cemetery).

Family	Plant Species	Ecobiomorph/Life Form	Abundance	Purpose
Asteraceae	*Inula britannica* L.	Mes/Per	Sol	medicinal
	Jacobaea vulgaris Gaertn.	Mes/Per	Sol	weedy, ornamental
	Cirsium arvense (L.) Scop.	Mes/Per	Sol	weedy
	Cichorium intybus L.	XerMes/Per	Cop1	medicinal, forage
	Tragopogon orientalis L.	XerMes/An	Sol	medicinal, ornamental
	Tragopogon dubius Scop.	XerMes/An	Sol	medicinal, ornamental
	Taraxacum officinale F.H.Wigg.	Mes/Per	Sp	medicinal, food plant
	Serratula marginata Tausch	Xer/Per	Sol	medicinal
	Silybum marianum (L.) Gaertn.	Mes/An	Cop1	medicinal, ornamental
	Carduus thoermeri Weinm.	Mes/An	Cop2	weedy
	Centaurea integrifolia Tausch	Xer/Per	Sol	medicinal
	Sonchus arvensis L.	Mes/Per	Sp	weedy
	Matricaria chamomilla L.	Mes/An	Sp	medicinal, honey plant

Table 2. *Cont.*

Family	Plant Species	Ecobiomorph/Life Form	Abundance	Purpose
Asteraceae	*Psephellus dealbatus* (Willd.) K.Koch	Xer/Per	Sol	ornamental
	Arctium tomentosum Mill.	Mes/Per	Sp	medicinal
	Artemisia dracunculus L.	XerMes/Per	Sp	food plant, medicinal
	Artemisia austriaca Jacq.	Xer/Per	Sp	medicinal
	Artemisia absinthium L.	Xer/Per	Sp	medicinal
	Achillea millefolium L.	Mes/Per	Sp	medicinal, ornamental
Rosaceae	*Sorbaria sorbifolia* (L.) A.Braun	Mes/Shr	Un	ornamental
	Potentilla erecta (L.) Raeusch.	Mes/Per	Sol	medicinal
	Spiraea salicifolia L.	Mes/Shr	Un	ornamental
	Rosa glabrifolia C.A.Mey. ex Rupr.	Mes/Shr	Un	ornamental
	Rosa canina L.	Mes/Shr	Sol	ornamental
	Amelanchier alnifolia (Nutt.) Nutt. ex M.Roem.	Mes/Shr	Un	food plant, ornamental
	Prunus fruticosa Pall.	Mes/Shr	Un	food plant, ornamental
	Crataegus sanguinea Pall.	Mes/Shr	Sol	medicinal, ornamental
	Sorbus aucuparia L.	Mes/tree	Un	food plant, ornamental
Brassicaceae	*Barbarea vulgaris* W.T.Aiton	Mes/Per	Sp	medicinal, weedy
	Thlaspi arvense L.	Mes/An	Sol	weedy, honey plant
	Lepidium draba L.	Mes/Per	Sol	medicinal, weedy
	Berteroa incana (L.) DC.	Xer/An	Cop1	weedy
	Peltaria turkmena Lipsky	Xer/Per	Cop1	medicinal
	Rorippa palustris (L.) Besser	Mes/Per	Sp	weedy
	Descurainia sophia (L.) Webb ex Prantl	Xer/An	Sol	medicinal, weedy
	Isatis tinctoria L.	Mes/Per	Sol	medicinal
Fabaceae	*Medicago falcata* L.	MesXer/Per	Cop1	forage, soil-improving
	Medicago sativa L.	Mes/Per	Cop1	forage, soil-improving
	Melilotus officinalis (L.) Lam.	Xer/An	Cop1	honey plant, medicinal
	Glycyrrhiza uralensis Fisch. ex DC.	XerMes/Per	Sp	medicinal, forage
	Onobrychis tanaitica Spreng.	Xer/Per	Cop2	forage, soil-improving
	Vicia cracca L.	Mes/Per	Cop1	forage, honey plant
	Trifolium pratense L.	Mes/Per	Sol	forage, honey plant
	Caragana frutex (L.) K.Koch	Xer/Shr	Sol	ornamental, forage
Poaceae	*Agropyron cristatum* (L.) Gaertn.	Xer/Per	Cop1	forage, weedy
	Calamagrostis epigejos (L.) Roth	Mes/Per	Sp	forage, weedy
	Poa pratensis L.	Mes/Per	Sp	forage, ornamental
	Elytrigia intermedia (Host) Nevski	XerMes/Per	Cop2	forage, soil-improving
	Bromus inermis Leyss.	Mes/Per	Sp	forage, soil-improving
	Agropyron repens (L.) P.Beauv.	MesXer/Per	Cop2	forage, weedy
Polygonaceae	*Polygonum aviculare* L.	Xer/An	Sp	medicinal, weedy
	Rumex longifolius DC.	Mes/Per	Sp	medicinal, weedy
	Rumex crispus L.	Mes/Per	Sol	medicinal, forage
Lamiaceae	*Salvia pratensis* L.	Mes/Per	Sp	medicinal, honey plant
	Salvia deserta Schangin	Xer/Per	Sol	medicinal
	Phlomis tuberosa L.	Mes/Per	Sp	medicinal
	Mentha asiatica Boriss.	Mes/Per	Sp	medicinal, honey plant
Apiaceae	*Carum carvi* L.	Mes/Per	Sol	food plant, medicinal
	Foeniculum vulgare Mill.	Mes/Per	Sol	food plant, medicinal
	Eryngium planum L.	Xer/Per		medicinal
Boraginaceae	*Lappula squarrosa* (Retz.) Dumort.	Xer/An	Un	weedy
	Symphytum asperum Lepech.	Mes/Per	Un	medicinal
	Nonea pulla (L.) DC.	Mes/An	Cop1	weedy

Table 2. *Cont.*

Family	Plant Species	Ecobiomorph/Life Form	Abundance	Purpose
Grossulariaceae	*Ribes saxatile* Pall.	Mes/Shr	Un	food plant, ornamental
Geraniaceae	*Geranium pratense* L.	Mes/Per	Sol	medicinal
Euphorbiaceae	*Euphorbia esula* L.	Xer/Per	Cop2	weedy
Convolvulaceae	*Convolvulus arvensis* L.	Xer/Per	Sol	weedy
Plantaginaceae	*Plantago major* L.	Mes/Per	Cop1	medicinal
Rubiaceae	*Galium ruthenicum* Willd.	Mes/Per	Sol	medicinal
Chenopodiaceae	*Atriplex sagittata* Borkh.	Xer/Per	Sp	forage
Solanaceae	*Hyoscyamus niger* L.	Mes/An	Sol	medicinal
Asparagaceae	*Asparagus officinalis* L.	Mes/Per	Sol	food plant, medicinal
Urticaceae	*Urtica dioica* L.	Mes/Per	Sp	food plant, medicinal
Campanulaceae	*Campanula rapunculoides* L.	Mes/Per	Un	ornamental
Caryophyllaceae	*Saponaria officinalis* L.	Mes/Per	Sol	medicinal
Ulmaceae	*Ulmus parvifolia* Jacq.	Mes/tree	Sol	ornamental
Salicaceae	*Populus alba* L.	Mes/tree	Sol	ornamental
Sapindaceae	*Acer platanoides* L.	Mes/tree	Sol	ornamental

Note: Cop1—many, Cop2—slightly more, Sp—often, frequently, Sol—few; Xer—Xerophyt, Mes—Mesophyt, XerMes—Xeromesophyt, MesXer—Mesoxerophyt; per—perennial, an—annual.

Among the recorded plant species, the most numerous families are Asteraceae with 20 species, Poaceae with six species, Fabaceae with eight species, Brassicaceae with eight species, and Rosaceae with nine species. Other families, including Lamiaceae with four species, Apiaceae with three species, Polygonaceae with three species, and Boraginaceae with three species, are less represented, with the remaining families having only one species each.

Regarding life forms, the plant community comprises 13 annual herbs, 53 perennial herbs, nine shrubs, and four tree species. In terms of ecological morphs, 19 species are classified as xerophytes, six species as xeromesophytes, two species as mesoxerophytes, and 52 species as mesophytes.

The Asteraceae family, which includes 20 species, displays diverse abundance across categories such as Sol, Sp, Cop1, and Cop2. The most abundant species within this family include *Cichorium intybus* (Cop1), *Silybum marianum* (Cop1), *Carduus thoermeri* (Cop2), *Matricaria chamomilla* (Sp), *Sonchus arvensis* (Sp), *Artemisia austriaca* (Sp), *Artemisia absinthium* (Sp), and *Achillea millefolium* (Sp). The Brassicaceae family is represented by eight species with abundance levels of Cop1, Sol, and Sp, with the most abundant species being *Berteroa incana* (Cop1) and *Peltaria turkmena* (Cop1).

The Fabaceae family also includes eight species with varying abundance levels, particularly Cop1, Cop2, Sp, and Sol. Among these, the most abundant species are *Medicago falcata* (Cop1), *Medicago sativa* (Cop1), *Melilotus officinalis* (Cop1), *Onobrychis tanaitica* (Cop2), and *Vicia cracca* (Cop1). The Poaceae family, with six species, shows abundance levels of Cop1, Cop2, and Sp, with the most abundant species being *Agropyron cristatum* (Cop1), *Elytrigia intermedia* (Cop2), and *Agropyron repens* (Cop2). The Euphorbiaceae family is represented by one species, *Euphorbia esula*, with an abundance level of Cop2.

Additionally, the Plantaginaceae family is represented by one species, *Plantago major*, with an abundance level of Cop1, while the Boraginaceae family includes three species with Un and Cop1 abundance levels, with *Nonea pulla* being the most abundant. Families with fewer species, such as Euphorbiaceae, Geraniaceae, and Boraginaceae, typically exhibit less frequent occurrences, often with lower abundance levels (Un and Sol).

The highest number of species belongs to weedy plants. Among these, species with a high abundance rating of Cop1 (very frequent) include *Agropyron cristatum* (Cop1), *Berteroa incana* (Cop1), *Peltaria turkmena* (Cop1), *Medicago falcata* (Cop1), *Medicago sativa* (Cop1), *Melilotus officinalis* (Cop1), *Vicia cracca* (Cop1), *Euphorbia esula* (Cop2), *Plantago major* (Cop1), *Cichorium intybus* (Cop1), and *Silybum marianum* (Cop1).

Forage plants are also well-represented in the list, with the most abundant species being *Calamagrostis epigeios* (Sp), *Poa pratensis* (Sp), *Bromus inermis* (Sp), *Elytrigia intermedia* (Cop2), *Agropyron repens* (Cop2), *Glycyrrhiza uralensis* (Sp), *Trifolium pratense* (Sol), and *Cichorium intybus* (Cop1).

Many species have medicinal properties, such as *Taraxacum officinale* (Sp), *Mentha asiatica* (Sp), *Achillea millefolium* (Sp), *Matricaria chamomilla* (Sp), and *Artemisia absinthium* (Sp).

Ornamental plants include species such as *Sorbaria sorbifolia* (Un), *Spiraea salicifolia* (Un), *Rosa glabrifolia* (Un), *Amelanchier alnifolia* (Un), and *Crataegus sanguinea* (Sol).

Honey plants are represented by species like *Matricaria chamomilla* (Sp), *Trifolium pratense* (Sol), and *Melilotus officinalis* (Cop1).

Although mesophytes have the highest species count, xerophytes dominate in terms of plant abundance: for example, *Agropyron cristatum* (Cop1), *Berteroa incana* (Cop1), *Peltaria turkmena* (Cop1), and *Artemisia absinthium* (Sp).

There are only two species classified as mesoxerophytes: *Agropyron repens* (Cop2) and *Medicago falcata* (Cop1).

Mesophytes are most frequently found with abundance ratings of Sp, Sol, and Un: for example, *Calamagrostis epigeios* (Sp), *Poa pratensis* (Sp), *Bromus inermis* (Sp), and Taraxacum officinale (Sp).

Xeromesophytes are mostly found with abundance ratings of Cop2 and Cop1, such as *Elytrigia intermedia* (Cop2) and *Cichorium intybus* (Cop1).

Our observations revealed that in Territory 2 (the cemetery area), mesophytic species such as *Poa pratensis*, *Taraxacum officinale*, and *Bromus inermis* were significantly more abundant. These species thrive in moist and shaded environments, which are created by the cemetery's dense tree cover and the shadows cast by monuments and tombstones. The physical structures within the cemetery reduce solar radiation and wind speed, leading to lower evapotranspiration rates and higher soil moisture levels.

In contrast, Territory 1 (the area surrounding the cemetery) was dominated by xerophytic species like *Agropyron cristatum*, *Artemisia austriaca*, and *Euphorbia esula*. These species are well-adapted to the open, arid steppe conditions prevalent outside the cemetery, where exposure to sunlight and wind is much higher and soil moisture is considerably lower.

4. Discussion

Cemeteries, as shown in numerous studies, play a crucial role not only as places of memory and cultural heritage but also as significant elements of urban ecosystems. They contribute to biodiversity conservation, impact climate regulation, and serve as refuges for rare and endangered plant species. Global studies confirm that cemeteries often surpass other urban green spaces in their conservation value. For instance, research in Southeast China has shown that culturally protected forests, including cemeteries, contain a significant number of protected plant species, making them important sites for biodiversity conservation [45]. In Turkey, old cemeteries in urban areas have been noted to support richer flora compared with green spaces in newer districts, highlighting their significance in urbanized settings [46]. Similar conclusions have been drawn in Ghana, where cemeteries play a key role in carbon sequestration, contributing to the reduction of the city's carbon footprint [47].

Research has demonstrated that cemeteries play a significant role in preserving plant biodiversity across various landscape types. Family cemeteries in agricultural landscapes in China were studied to assess their contribution to maintaining plant diversity. The research examined 199 family cemeteries of varying ages and sizes, finding that plant species richness, including insect-pollinated species, increased with the age and size of the cemeteries. This underscores the critical role of cemeteries as semi-natural habitat islands, especially in intensively used agricultural landscapes [48].

Old cemeteries in the Lower Dnipro region (Southern Ukraine) were also found to be important for the conservation of vascular plants. Research conducted on 13 cemeteries identified 440 plant species, including rare and steppe species, highlighting the role of cemeteries as islands of steppe habitats in heavily transformed landscapes [49].

In Berlin, studies demonstrated the high biological richness of a large urban cemetery. A multi-taxon analysis at the Weißensee Jewish Cemetery recorded 608 species of plants and animals, confirming the significant ecological value of such areas in urban environments [50].

Cemeteries in Istanbul were examined for their role as green urban spaces. At the Aşiyan Cemetery, 280 plant species were identified, emphasizing the importance of these areas in maintaining urban plant diversity [34].

Polish cemeteries, such as those in Citadel Park in Poznań, also showed a diverse range of vascular plants. This study recorded 255 species in these cemeteries, underscoring their importance in preserving floral diversity, including both spontaneous and cultivated species [51].

Research indicated that cemeteries in rural areas can serve as refuges for steppe flora. For instance, in the village of Salikhovo in Bashkortostan, 126 species of vascular plants were identified, most of which are mesophytes, emphasizing their significance in preserving local biodiversity under anthropogenic pressure [52].

The vegetation cover of the All Saints Cemetery in Tula was studied in two phases, revealing 359 plant species. This study showed that the cemetery maintains high species diversity, which can serve as a foundation for further research into the ecosystem functions of cemeteries [53].

Yegoshikha Cemetery in Perm was also studied, revealing 202 species of vascular plants. The analysis showed a dominance of mesophytes, highlighting the importance of these areas for maintaining ecological balance in urban conditions [54].

Research in Hungary and Northern Italy has demonstrated that old cemeteries are important sites for preserving steppe and meadow plant species, including rare and invasive species [55]. These studies underscore the importance of cemeteries as biodiversity refuges, particularly in the context of intensive urbanization and climate change.

Our research at Tikhonov Cemetery further supports these findings, where 79 plant species belonging to 23 families were recorded, significantly exceeding the species diversity in the adjacent area, where only 31 species from 11 families were found. These data indicate that cemeteries can serve as important biodiversity centers even in urban environments, which is consistent with similar international studies [56].

An eco-morphological analysis revealed significant differences between the flora on the cemetery grounds and the adjacent area. Mesophytes (52 species) dominate in the cemetery, indicating more humid and favorable conditions for plants. This could be due to the presence of shrubs and trees that provide shade and reduce water evaporation, as well as possibly lower anthropogenic pressure. In contrast, xerophytes (10 species) dominate in the surrounding area, indicating drier conditions and greater exposure to anthropogenic impacts. These differences align with other studies showing that cemeteries, due to their isolation and specific conditions, can support more diverse and resilient ecosystems [57].

An important aspect is the diversity of plant life forms. Perennial grasses (53 species) dominate the cemetery, while only 25 species of perennial grasses are recorded in the adjacent area, with no shrubs or trees. This confirms the more complex and resilient ecosystem structure in the cemetery, consistent with international research where cemeteries are considered refuges for rare and protected plant species [35]. The presence of various eco-morphological groups on the cemetery grounds, such as xeromesophytes and mesoxerophytes, also indicates diverse microclimatic conditions, making cemeteries unique places for maintaining biodiversity in urban settings.

Cemeteries create unique ecological niches due to several interrelated factors that distinguish them from other urban environments. Firstly, they are often relatively undisturbed areas within cities, characterized by limited human activity and infrequent maintenance practices [28]. This minimal disturbance allows for the development of more stable and resilient ecosystems, providing habitats for rare and sensitive plant species that cannot compete in more intensively managed urban spaces. Some areas of cemeteries may even be abandoned or less frequented, enabling natural vegetation succession and the establishment of native species [30].

Secondly, the architectural features of cemeteries—such as monuments, tombstones, crypts, and fences—contribute significantly to the creation of diverse microclimatic conditions. These structures offer shade, reduce wind speeds, and help retain soil moisture, modifying the local environment in ways that differ markedly from the surrounding landscapes. For example, in Tikhonovskoye Cemetery, these modifications result in microhabitats with different levels of light, temperature, and humidity, supporting a diverse range of plant ecobiomorphs, including mesophytes and even hygrophytes in arid climates.

The dominance of mesophytic species within cemeteries highlights the significant role these structures play in creating favorable microclimates. Shaded areas under trees and near monuments have lower temperatures and reduced evapotranspiration rates, which help maintain higher soil moisture levels. This environment supports the growth of mesophytes that require consistent moisture and cannot typically survive in the harsher conditions of open steppe or urban settings. Similar findings were reported by Stumpe et al. [27], who demonstrated that urban cemeteries act as cooling islands due to their vegetation and structures, creating more stable humidity and temperature levels.

Thirdly, the specific soil composition in cemeteries enhances their role as unique ecological niches. The soils are often enriched with organic matter from decomposing plant material and minimal soil disturbance due to limited human activity [58]. This enrichment results in looser, more fertile soils that promote deeper root systems and enhance plant resilience to stressful conditions. Additionally, the accumulation of organic matter and reduced soil compaction in less-trodden areas further improve soil fertility and structure, creating even more conducive environments for moisture-loving plants [59].

The cemetery thus functions as a refugium for various plant species, allowing them to persist in an otherwise inhospitable landscape. The presence of a higher number of perennial herbs, shrubs, and trees contributes to habitat complexity, supporting greater biodiversity. Human influences, such as the traditional planting of ornamental and memorial plants around graves, also increase species diversity by introducing non-invasive species. Our results are consistent with studies by Planchuelo et al. [55], who found that cemeteries provide critical habitats for endangered plant species by offering unique microclimates within urban settings. These findings underscore the ecological importance of cemeteries as biodiversity hotspots. They highlight the need for conservation strategies that recognize and preserve the unique environmental conditions of cemeteries, particularly in arid urban environments facing the challenges of climate change.

Comparing these two areas shows that the cemetery has a broader range of habitats, supporting plant diversity and contributing to the creation of sustainable ecosystems. Meanwhile, the adjacent area, subject to greater anthropogenic pressure, is characterized by lower species diversity and a predominance of xerophytes and mesophytes, indicating drier and less favorable conditions for plants. This is confirmed by international studies emphasizing the importance of cemeteries in urbanized zones for biodiversity conservation and air quality improvement [60,61].

Cemeteries, as shown in studies, can serve as refuges for rare and endangered plant species even in conditions of intensive urbanization. In Poland and the Sverdlovsk region, cemeteries serve as centers for the spread of alien plant species, requiring measures for their conservation and improvement of biodiversity [62,63]. In our study, we found *Campanula rapunculoides* (Campanulaceae), which is included in the Red Books of some regions of the Russian Federation [64].

Our research underscores the critical role that cemeteries play in preserving biodiversity, particularly under the increasing challenges posed by climate change. Unlike surrounding areas, the cemetery supports a unique microclimate created by its monuments, tombstones, and the presence of artificially planted trees and shrubs. This distinct microclimate fosters the survival and proliferation of mesophytic (moisture-loving) plants, which would otherwise struggle to thrive in the drier, more arid conditions prevalent in the surrounding landscape.

As the global climate continues to warm and droughts become more frequent, the ability of cemeteries to maintain stable and humid microclimates becomes increasingly significant. The cemetery's environment, characterized by shaded areas and reduced soil moisture loss, creates a refuge for mesophytes, which require more consistent moisture levels to survive. In this sense, the cemetery acts as a refugium, safeguarding the biodiversity of mesophytic species that are vulnerable to the harsher, more xerophytic conditions outside its boundaries.

Cemeteries, with their unique structural features and microclimate, play a crucial role in preserving biodiversity, especially for moisture-dependent plant species under the pressures of climate change. This makes them indispensable in efforts to maintain ecological balance and biodiversity in increasingly arid environments.

5. Conclusions

These findings highlight the crucial role cemeteries play as biodiversity refuges, particularly in urban settings where natural habitats are limited. To capitalize on this potential, practical steps can be taken to enhance the biodiversity value of cemeteries within urban biodiversity management:

1. Integrate cemeteries into urban planning: Urban planners and policymakers should recognize cemeteries as important green spaces and include them in urban biodiversity and green infrastructure plans. This integration ensures that cemeteries are managed not only for their cultural and memorial functions but also for their ecological value.
2. Implement biodiversity-friendly management practices: Cemetery management should adopt practices that promote biodiversity, such as reducing mowing frequency to allow native plants to flower and set seed, thereby supporting pollinators and other wildlife. Minimizing the use of herbicides and pesticides also helps preserve species diversity.
3. Promote native and drought-resistant plantings: Encouraging the planting of native and drought-resistant species that are well-adapted to local conditions can enhance the ecological value and resilience of cemetery ecosystems. These plants require less water and maintenance, making them ideal for the sustainable management of cemetery landscapes.
4. Enhance habitat diversity: Maintaining and creating a variety of microhabitats within cemeteries—such as wooded areas, shrublands, meadows, and wildflower patches—can support diverse plant and animal species. This habitat diversity contributes to the overall ecological complexity and resilience of urban green spaces.
5. Foster community engagement and education: Cemeteries can serve as educational sites to raise public awareness about urban biodiversity. Involving local communities in conservation efforts and promoting respectful recreational use can foster a sense of stewardship and enhance the social value of these spaces.
6. Conduct regular biodiversity assessments: Implementing monitoring programs to track biodiversity changes over time can inform adaptive management strategies and demonstrate the ecological value of cemeteries. Such assessments can guide future conservation efforts and policy decisions.
7. Collaborate with stakeholders: Collaboration among ecologists, urban planners, cemetery managers, and local communities is essential for developing and implementing effective biodiversity management strategies in cemeteries. Sharing knowledge and resources can maximize the ecological and social benefits of these spaces.

By adopting these practical measures, cemeteries can serve not only as places of cultural and historical significance but also as vital components of urban ecosystems, contributing to biodiversity conservation, climate adaptation, and improved quality of life for urban residents. Such initiatives are particularly important in the face of climate change, as cemeteries can provide stable microclimates that support moisture-loving species in increasingly arid environments.

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