



Ecological status and taxonomic diversity of urban green plantings of Astana, Kazakhstan

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ABSTRACT

Urban green spaces are a key element in the conservation of biological diversity and the maintenance of environmental sustainability under conditions of intensive urbanization, especially in regions with a sharply continental climate. This paper presents a comprehensive analysis of the ecological status, sanitary condition, and taxonomic diversity of tree and shrub plantings in the city of Astana (Kazakhstan) based on field inventory data and geoinformation analysis. During the study, 1,345,872 specimens of tree and shrub plants belonging to 155 species, forms, and cultivars, 61 genera, and 27 families were recorded. The taxonomic structure is dominated by the families Rosaceae (30.3%), Pinaceae (9.0%), and Salicaceae (9.0%). Deciduous species account for 85.4%, and coniferous species for 14.6% of the total number of plantings. According to the results of the sanitary assessment, more than 69.0% of plants belong to the sanitary condition category I (healthy). *Salix alba* and *Populus nigra* proved to be the most resistant to urban environmental conditions. Spatial analysis revealed pronounced differences between the administrative districts of the city, determined by the history of urban development, the level of anthropogenic load, and the intensity of maintenance of green spaces. The obtained results emphasize the importance of systematic GIS-based inventory as a tool for monitoring urban biodiversity and for developing scientifically grounded strategies for sustainable management of green infrastructure in cities with a continental climate.

Keywords: Urban biodiversity, Green infrastructure, Dendroflora, Sanitary condition, GIS inventory, Urbanized ecosystems.

Article type: Research Article.

INTRODUCTION

Modern cities are considered not only as centers of anthropogenic transformation of the natural environment, but also as important elements of regional ecological networks capable of supporting significant biological diversity. Under conditions of global urbanization, urban green spaces perform key ecological functions, including microclimate regulation, reduction of pollution levels, biodiversity conservation, and improvement of the quality of life of the population. Green infrastructure is of particular importance in cities located in zones with a sharply continental climate, where extreme temperature fluctuations, moisture deficiency, soil compaction, and environmental pollution form a complex of stress factors that significantly affect plant viability and the structure of urban dendroflora (Mukanov *et al.* 2010; Shevchenko 2014). Under such conditions, the sustainability of green plantings is determined by species composition, ecological plasticity of the taxa used, and the effectiveness of urban greening management systems. Within the framework of the Convention on Biological Diversity and the



Global Strategy for Plant Conservation, the necessity of systematic inventory and monitoring of plant resources, including those in urbanized landscapes, is emphasized (Convention on Biological Diversity 1992; Convention on Biological Diversity 2002; Report 2006; Global Strategy 2025). Despite the active development of greening programs in the Republic of Kazakhstan, comprehensive studies focused on analyzing the taxonomic diversity and ecological status of urban plantings using GIS technologies remain insufficiently represented. A number of studies indicate that under urban conditions plants face a reduction in life cycle duration, decreased productivity, and damage to leaf and needle apparatus (Frolov 1998). Surveys of cities in Kazakhstan show that up to 60–70% of plantings require reconstruction and do not fully perform their ecological functions (Sarsekova *et al.* 2018). At the same time, for the city of Astana, an expansion of the range of plant species used and an increase in green areas have been noted, which highlights the need for their comprehensive assessment (Besschetnov *et al.* 1979; Avdeeva 1994; Morozova *et al.* 2003; Latushkina, & Kudaibergenova 2017). Effective management of urban green infrastructure is impossible without systematic inventory of green spaces, which provides reliable information on taxonomic composition, spatial distribution, and sanitary condition of plants (Munn 1983; Wirth 1995; European Treeworker 2002). The use of geographic information systems allows the integration of spatial and attributive data, increases accounting accuracy, and creates a basis for long-term monitoring of the state of urban vegetation (Krasilnikova 2015; Lekareva 2019; Vavilova 2019). The city of Astana, located in the steppe zone with a sharply continental climate and characterized by intensive urbanization, represents a representative model for studying the sustainability and structural features of urban vegetation. Despite significant volumes of greening activities, a comprehensive assessment of the taxonomic diversity and sanitary condition of tree and shrub plantings in the city has remained fragmented to date. The purpose of this study is to conduct a comprehensive inventory of urban green plantings in Astana using GIS technologies to assess their sanitary condition, taxonomic diversity, spatial structure, and sustainability within the administrative districts of the city.

MATERIALS AND METHODS

Object and Study Area

The object of the study was tree and shrub plantings growing within the urban territory of Astana (Kazakhstan). The city is located in the steppe zone with a sharply continental climate, characterized by significant seasonal and daily temperature fluctuations, limited moisture availability, and high anthropogenic pressure.

The study covered four administrative districts of the city - Yesil, Almaty, Saryarka, and Baikonur - differing in functional zoning, age of development, population density, and level of anthropogenic impact. Such zoning made it possible to assess the spatial heterogeneity of the structure and condition of urban green plantings.

Inventory of Green Plantings

The inventory of green plantings was carried out during the field season using a complete census method with route-based and plot-based approaches. A total of 330 accounting plots were established, covering the main types of urban green spaces: parks, squares, boulevards, street plantings, intra-block territories, and protective plantings. For each specimen of tree and shrub plants, the following parameters were recorded: taxonomic affiliation; life form (tree, shrub); quantitative indicators; qualitative characteristics; sanitary condition (Espolov *et al.* 2008; Sarsekova 2014).

Primary data collection was carried out under field conditions with subsequent verification of attributive information based on orthophotos and remote sensing materials. Spatial referencing of objects and data visualization were performed using the mobile GIS application Field Maps, while further processing and analysis were carried out in ArcGIS software. This made it possible to create a multilayer digital map of the city's green fund with detailed attribute tables.

Assessment of Sanitary Condition

The sanitary condition of tree and shrub plants was assessed using a six-point scale (Maysupova & Toktasynov 2009; Minister of Agriculture of the Republic of Kazakhstan 2015; Telegina & Vibe 2016), widely applied in forest pathological and urban ecological studies. According to this scale, the following condition categories were distinguished:

I - healthy: dense crown, green leaves/needles, no signs of damage or dieback;

II - weakened: slight crown thinning, partial damage to leaves/needles (up to 25%), dieback of individual branches;

III - severely weakened: pronounced crown thinning, weak or absent increment, dieback of up to 2/3 of the crown, presence of water shoots and signs of pest damage;

IV - drying: dieback of more than 2/3 of the crown, significant damage to the trunk and root system;

V - fresh deadwood: plants that died in the current year, foliage absent or completely dried;

VI - old deadwood: plants that died in previous years, bark and small branches partially or completely lost. The applied methodology made it possible to objectively assess plant viability and identify areas requiring priority sanitary measures or reconstruction.

Taxonomic analysis

Taxonomic identification of tree and shrub plants was carried out using classical dendrological keys, as well as electronic databases and the PlantNet mobile application. Taxonomic analysis was conducted at the family, genus, and species levels with assessment of their relative contribution to the overall structure of urban dendroflora.

Species nomenclature is given in accordance with modern botanical sources (Vanin 1997; Suntsova *et al.* 2010; Kurovskaya & Kuklina 2011; Kayukov & Popov 2020). At the final stage of inventory work, an ecological interpretation of the obtained data was performed, which made it possible to identify key trends in the formation of urban dendroflora and to develop recommendations for increasing the sustainability and ecological efficiency of the city's green plantings (Mambetov 2015). To assess species diversity of tree plantings by districts of Astana, the Shannon species diversity index (H') was used, calculated according to the formula:

$$H' = - \sum_{i=1}^S p_i \ln p_i$$

where:

H' - Shannon species diversity index;

S - total number of tree species in the plantings of the studied district;

p_i - relative abundance of the i -th species, defined as the ratio of the number of individuals of this species (n_i) to the total number of recorded individuals of all species (N); \ln - natural logarithm.

The calculation was performed separately for each district based on the actual abundance of all species presented in Table 1. All districts showed broad species representation (more than 80 taxa); however, the distribution of abundance among species was highly uneven.

Table 1. Total number of tree plantings by districts.

| District No | Administrative district | Total number (pcs.) |
|-------------|-------------------------|---------------------|
| 01 | Yesil | 269 098 |
| 02 | Almaty | 219 111 |
| 03 | Saryarka | 138 367 |
| 04 | Baikonur | 92 307 |

RESULTS

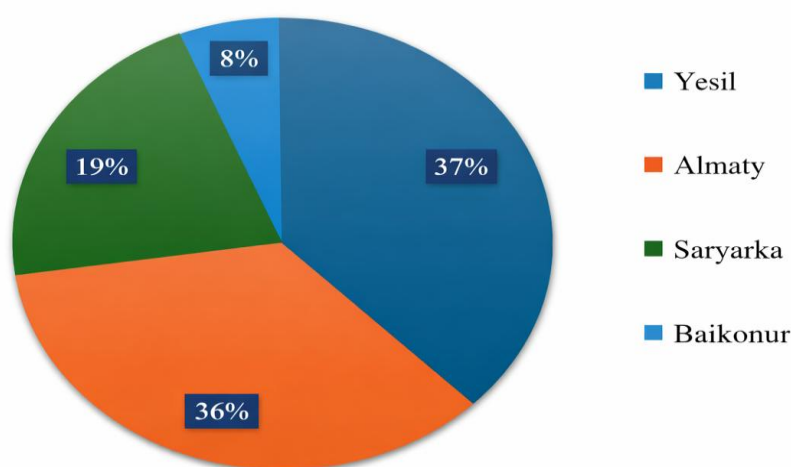
Quantitative and Spatial Structure of Green Plantings

As a result of the inventory, 1,345,872 specimens of tree and shrub plants were recorded within the territory of Astana, of which 94% are trees and 6% are shrubs. In addition, 212,943.5 linear meters of hedges, 168,969.53 m² of flower beds, and 19,868,704.47 m² of lawn areas were recorded, reflecting the integrated nature of the city's green infrastructure. The spatial distribution of green plantings is characterized by pronounced heterogeneity between the administrative districts of the city (Table 2, Fig. 1). The highest concentration of tree and shrub plants was recorded in the Yesil (36.64%) and Almaty (36.45%) districts, which is due to more active development of new-type residential quarters, the presence of large recreational zones, and more intensive implementation of landscape greening programs. The Saryarka district contains 18.57% of all recorded plantings, whereas the Baikonur district is characterized by minimal provision of green plantings (8.33%). A similar pattern is observed for other greening categories (hedges, flower beds, and lawns), indicating uneven spatial distribution of green infrastructure within the city. Quantitative indicators of greening are complemented by differences in planting density per unit area (Fig. 2). Maximum density values are observed in central and new residential zones, whereas areas with high building density and developed transport infrastructure show a deficit of tree and shrub elements. Spatial analysis showed that the share of tree and shrub plantings varies from 36.6% in the most greened Yesil district to 8.3% in the Baikonur district. These differences reflect the influence of stages of urban development, functional zoning, and the degree of anthropogenic transformation of the urban territory.

Table 2. Results of the inventory of green plantings by administrative districts of Astana

| District | Tree and shrub plantings (pcs.) | Hedges, (lm) | Flower beds (m ²) | Lawns (m ²) |
|----------|---------------------------------|--------------|-------------------------------|-------------------------|
| Yesil | 493,180 | 104,762.0 | 97,892.32 | 8,423,593.5 |
| Almaty | 490,619 | 64,317.0 | 31,456.01 | 7,515,812.5 |
| Saryarka | 249,907 | 30,938.2 | 29,890.91 | 2,244,009.7 |
| Baikonur | 112,166 | 12,926.3 | 9,730.29 | 1,685,288.8 |
| Total | 1,345,872 | 212,943.5 | 168,969.53 | 19,868,704.5 |

Tree and shrub plantings, %

**Fig. 1.** Share of tree and shrub plantings by districts.

Sanitary Condition of Tree and Shrub Plantings

Analysis of sanitary condition showed that, in general, green plantings of Astana are characterized by a favorable life state. Category I (healthy plants) includes 69.42% of the total number of recorded specimens. The proportion of weakened and suppressed plants increases in districts with high transport load, compacted development, and the presence of overmature plantings (Fig. 3; Table 3). The highest indicators of life condition were recorded in the Baikonur district, where, despite minimal overall provision with green plantings (8.33%), a relatively high percentage of healthy plants (74.4%) was identified. This may be due to lower building density, more even distribution of plantings, and the presence of relatively young plantings that have not yet entered the phase of age-related weakening. Weakened plants account for 20.6%, and the share of hazardous and dead plantings does not exceed 1.2%. However, the low absolute number of tree and shrub plants in this district limits its ecosystem functions and requires expansion of greened areas. In the Yesil and Almaty districts, the proportion of Category I plants is 70.4–72.7%, weakened plants account for 26.3%. Suppressed and drying plants are represented to a lesser extent (about 2%), and hazardous specimens account for only 0.1%, which indicates relatively favorable growing conditions, regular maintenance, and a more rationally selected assortment of species. At the same time, the increased proportion of weakened plants indicates the need for preventive measures. The most unfavorable situation was identified in the Saryarka district, where the share of healthy plantings is only 58.7%, and the combined share of weakened and suppressed plants exceeds 38%. This trend is likely due to high building density, significant transport load, high anthropogenic pressure, soil compaction, and moisture deficit, which are especially critical under sharply continental climate conditions. These factors lead to a decrease in tree vitality, accelerated aging, and increased susceptibility to biotic and abiotic stresses.

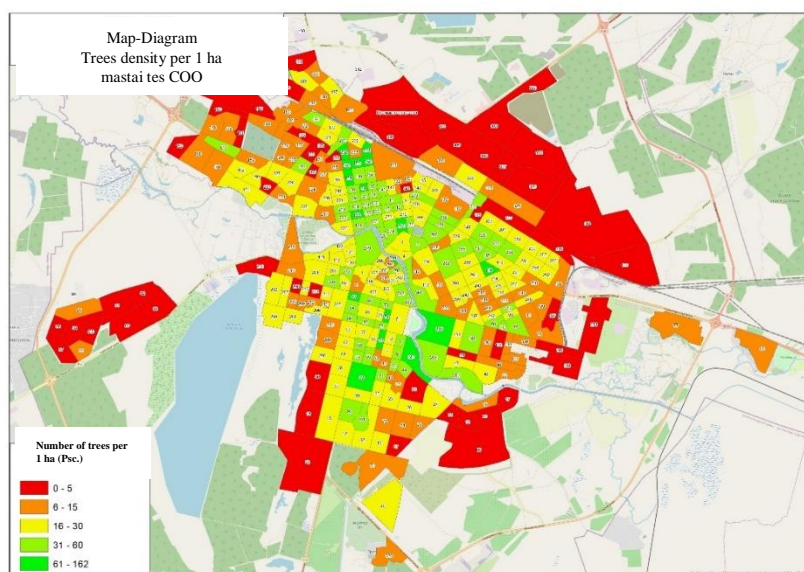


Fig. 2. Map of density of tree and shrub plantings in Astana per 1 ha.

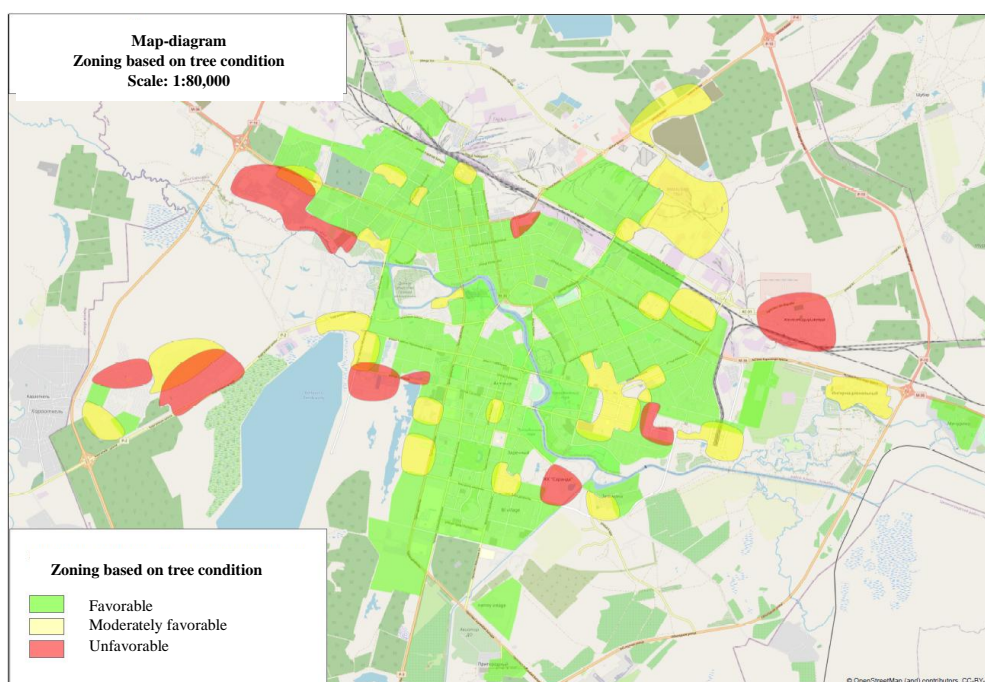


Fig. 3. Zoning map by condition of green plantings.

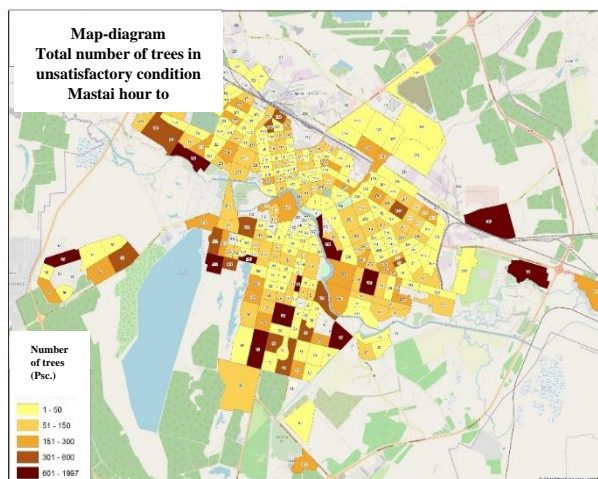
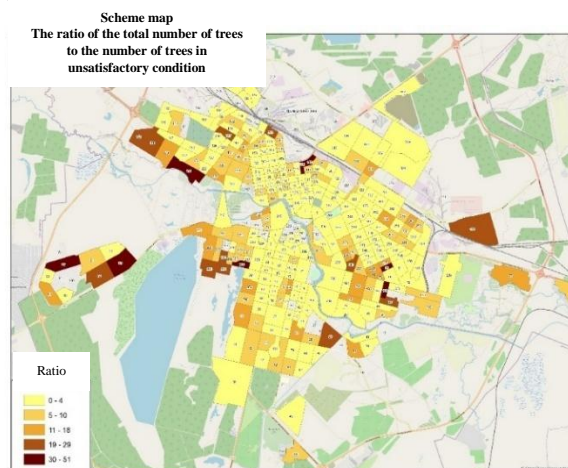
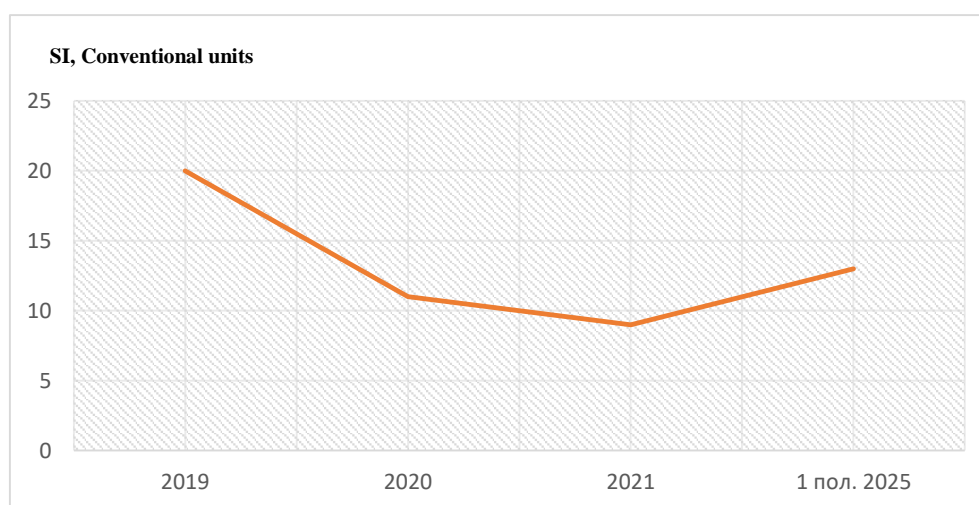
Spatial localization of plantings in unsatisfactory condition is mainly confined to major roads, industrial zones, and areas with old engineering infrastructure (Figs. 4, 5). These zones require priority measures for sanitary felling, reconstruction of plantings, and optimization of agrotechnical maintenance. Among tree species, the greatest resistance to urban environmental conditions was demonstrated by *Salix alba* and *Populus nigra*, which are characterized by high ecological plasticity and the ability to adapt to a complex of abiotic and anthropogenic stresses.

Analysis of the Atmospheric System State

According to data on ambient air quality (source: *Development of Target Environmental Quality Indicators for the City of Astana*, LLP “Nomad Eco”), the highest level of air pollution was recorded in 2019 (Fig. 6). In subsequent years, a decrease was observed; however, in the first half of 2025, an increase in pollutant concentrations was again recorded [*Development of Target Environmental Quality Indicators for the City of Astana*, LLP “Nomad Eco”].

Table 3. Distribution of tree and shrub plants by sanitary condition categories in the administrative districts of Astana.

| District | A condition category (pcs., /%) | | | | | |
|----------|---------------------------------|----------|------------|--------|----------|-----------|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| | Healthy | Weakened | Suppressed | Drying | Deadwood | Hazardous |
| Yesil | 358 601 | 104 853 | 13 512 | 8 503 | 6 347 | 1 364 |
| | 72.71% | 21.26% | 2.74% | 1.72% | 1.29% | 0.28% |
| Almaty | 345 450 | 129 203 | 5 921 | 3 966 | 5 689 | 390 |
| | 70.40% | 26.30% | 1.20% | 0.80% | 1.20% | 0.10% |
| Saryarka | 146 747 | 85 252 | 9 239 | 2 906 | 4 676 | 1 087 |
| | 58.70% | 34.10% | 3.70% | 1.20% | 1.90% | 0.40% |
| Baikonur | 83 462 | 23 055 | 3 237 | 1 117 | 1 108 | 187 |
| | 74.40% | 20.60% | 2.90% | 1% | 1% | 0.20% |

**Fig. 4.** Number of trees in unsatisfactory condition.**Fig. 5.** Ratio of the total number of tree and shrub plantings in unsatisfactory condition.**Fig. 6.** Dynamics of the Air Pollution Index in the city of Astana in 2019–2025.

The schematic map “Zoning by the dispersion of maximum ground-level concentrations of sulfur dioxide within the city of Astana” clearly demonstrates that the main zones of atmospheric air pollution are formed predominantly around industrial sites. The greatest contribution is made by large stationary sources—primarily thermal power

plants (CHPs). In the central districts of the city, a significant load on the atmospheric environment is exerted by mobile sources of pollution, mainly motor vehicles. In these areas, maximum concentrations are observed not only for sulfur dioxide but also for other priority pollutants (nitrogen dioxide, carbon monoxide, suspended particulate matter, etc.), which is explained by the high density of traffic flows.

Thus, sources of atmospheric air pollution in Astana can be divided into two main categories:

Stationary sources - industrial enterprises, primarily combined heat and power plants (CHPs), as well as the residential sector using stove heating.

Mobile sources - motor vehicles concentrated in the central and main arterial zones of the city.

This distribution of pollution sources determines the specifics of environmental zoning of the capital's territory and requires the development of differentiated measures to reduce the load on atmospheric air depending on the dominant type of anthropogenic impact.

At present, according to data from the Republican State Enterprise on the Right of Economic Management "Kazhydromet," the overall state of atmospheric air in the city of Astana is assessed as characterized by an increased level of pollution. The main factor determining the degree of atmospheric pollution is the volume and structure of pollutant emissions.

A total of 138 types of pollutants enter the city's atmosphere annually, including: 7 substances of hazard class I; 26 substances of hazard class II; 39 substances of hazard class III; 17 substances of hazard class IV; and 46 substances classified as having a safe level of impact (for which toxicological assessment for humans and ecosystems is being clarified) [*Development of Target Environmental Quality Indicators for the City of Astana*, LLP "Nomad Eco"].

The largest share in the emission structure is represented by sulfur dioxide (46.1%), inorganic dust with silicon dioxide content of 20–70% (19.43%), nitrogen dioxide (14.97%), and carbon monoxide (14.3%).

Characteristics of Major Pollutants

Nitrogen dioxide. (code 0301, hazard class II). The main zones of pollution by this substance are concentrated in the northern and central parts of the city. In the northern districts, the main contribution is made by industrial enterprises, whereas in the city center pollution is predominantly associated with motor vehicles. Maximum concentrations of nitrogen dioxide (up to 20.8 MPC) are recorded in the northeastern sector under unfavorable meteorological conditions. The largest source is motor transport (up to 91% of the total contribution, especially in the area of the intersection of Al-Farabi Street and A. Pushkin Street), while industrial enterprises (Municipal State Enterprise Elorda Eco System 2, CHP-2 of JSC "Astana-Energia") contribute about 9%.

Sulfur dioxide. (code 0330, hazard class III) (Fig. 7). Zones of increased concentrations of this substance are noted in the area of the intersection of Mangilik El Avenue and Saraishyk Street, as well as under unfavorable meteorological conditions near CHP-2 of JSC "Astana-Energia".

Suspended particulate matter. (hazard class III). In the summer period, zones of increased pollution are formed in the northern, northwestern, and northeastern parts of the city, where industrial enterprises are located.

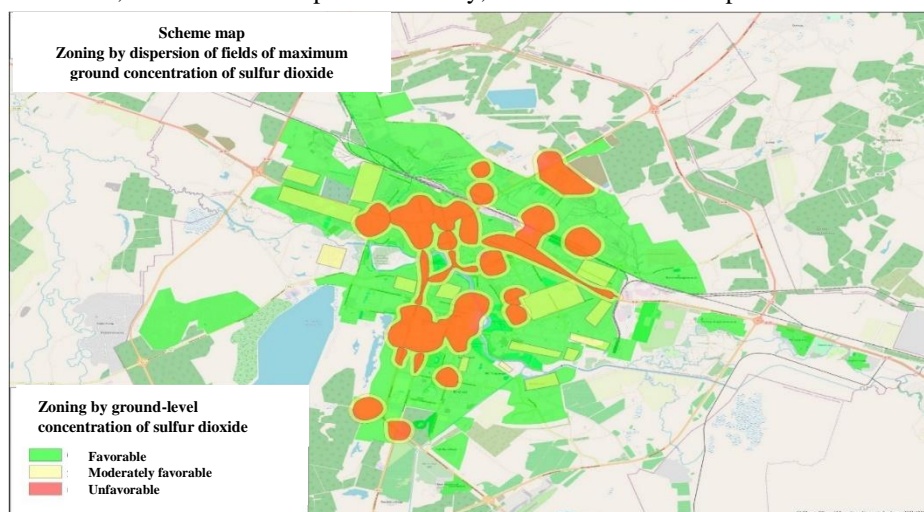


Fig. 7. Schematic map of zoning by dispersion of maximum ground-level concentrations of sulfur dioxide in the city of Astana.

The greatest contribution to pollution is made by LLP “Ecolife Astana,” LLP “BIOGENIC Developments,” and LLP Production Association “Beton.” The maximum calculated concentration of suspended substances in summer reaches 1.93 MPC.

Spatial distribution of pollution

Based on the analysis of calculated ground-level concentrations of pollutants, the following districts of the city of Astana are identified as being subjected to the most intensive anthropogenic impact: northern, northeastern, northwestern, and central districts. These territories form a zone of increased environmental risk, which requires the development and implementation of targeted measures to reduce pollutant concentrations and stabilize atmospheric air quality.

Biotic damage: Pests, diseases, and entomophages

During the surveys, 8 species of insect pests were identified, of which 5 species affect deciduous tree species, 1 species affects conifers; additionally, 2 types of diseases of deciduous species and 4 species of entomophages were recorded. The identified phytophages include representatives of the orders Hymenoptera, Diptera, Hemiptera, and Lepidoptera, while stem pests are represented by beetles from the families Cerambycidae and Curculionidae. The identified diseases are predominantly bacterial in nature (*Erwinia multivora*, *E. amylovora*) and are localized in weakened plantings (Fig. 8). The presence of entomophages, in particular representatives of the families Braconidae, Chrysopidae, and Tachinidae, indicates partial functioning of biological regulation mechanisms of pest populations in urban ecosystems. In general, the distribution of pests and diseases is focal in nature and is confined to areas with weakened sanitary conditions of plantings, which emphasizes the importance of regular monitoring and preventive measures.

Taxonomic diversity of urban dendroflora

Taxonomic analysis showed that tree and shrub plantings of Astana are represented by 155 species, forms, and cultivars belonging to 61 genera and 27 families (Table 4). The dominant position is occupied by the family Rosaceae, which includes 47 taxa (30.3%), reflecting its widespread use in ornamental, protective, and street landscaping. A significant contribution is also made by the families Pinaceae and Salicaceae, each represented by 14 taxa (9.0% each). Other families-Caprifoliaceae, Fabaceae, Berberidaceae, Betulaceae, Aceraceae, Malvaceae, etc.-include from six to one species (Fig. 8). At the genus level, the greatest diversity is observed in *Spiraea* and *Juniperus* (11 taxa each), *Populus*, *Acer*, and *Salix* (8 taxa each), as well as *Picea*, *Betula*, *Fraxinus*, *Syringa*, and *Rosa* (3–5 species each) (Fig. 9). The Saryarka District has $H' = 2.21$, indicating moderately reduced species diversity. The decrease in the index is due to a smaller total number of plantings, a high proportion of dominant species, and a relatively poor assortment of ornamental species. The minimum Shannon index value was recorded in the Baikonur District ($H' = 2.4$). Despite satisfactory sanitary condition of the plantings, the district is characterized by the smallest number of trees, a limited species spectrum, and a pronounced concentration of several dominant species. In terms of life forms, deciduous plants predominate, accounting for 85.4% of the taxonomic composition (135 species, forms, and cultivars), of which 64 are trees and 71 are shrubs. Coniferous plants are represented by 23 taxa (14.6%), including 15 tree and 8 shrub forms. In quantitative terms, deciduous plantings amount to 1,160,688 specimens, while coniferous plantings amount to 185,184 specimens. The dominance of a limited number of taxa (Fig. 10) ensures relative stability of green plantings through the use of well-adapted species; however, it simultaneously creates a risk of biological homogenization of the urban dendroflora and increased vulnerability to mass outbreaks of pests and diseases.

Table 4. Main species of tree and shrub plants growing in the city of Astana

| No. | Genus, Species | Family |
|-----|---|----------|
| 1 | 2 | 3 |
| | <i>Abies sibirica</i> Ledeb. | |
| | <i>Picea glauca</i> (Moench) Voss. | |
| | <i>P. abies</i> (L.) H. Karst. | |
| | <i>P. obovata</i> Ledeb. | |
| | <i>P. pungens</i> Engelm. | |
| | <i>P. pungens f. argentea</i> (R.C.Rosenthal) Beissn. | Pinaceae |
| | <i>Pinus koraiensis</i> Siebold & Zucc. | |
| | <i>P. mugo</i> "Turra" | |
| | <i>P. sibirica</i> Du Tour | |
| | <i>P. sylvestris</i> L. | |

| | |
|--|---------------|
| <i>P. sylvestris</i> 'Watereri' | |
| <i>Larix gmelini</i> (Rupr.) Rupr. | |
| <i>L. decidua</i> Pendula | |
| <i>L. sibirica</i> Ledeb. | |
| <i>Acer campestre</i> L. | |
| <i>A. platanoides</i> L. | |
| <i>A. negundo</i> L. | |
| <i>A. ginnala</i> Maxim. | |
| <i>A. rubrum</i> L. | Aceraceae |
| <i>A. rubrum</i> «Red Sunset» | |
| <i>A. rubrum</i> «Royal Red» | |
| <i>A. tataricum</i> L. | |
| <i>Amelanchier alnifolia</i> (Nutt.) Nutt. ex M. Roem. | |
| <i>Am. ovalis</i> Medikus | |
| <i>Am. spicata</i> (Lam.) K. Koch | |
| <i>Amygdalus nana</i> L. | |
| <i>Aronia melanocarpa</i> (Michx.) Elliott | |
| <i>Dasiphora fruticosa</i> (L.) Rydb. | |
| <i>Cerasus fruticosa</i> Pall. | |
| <i>C. tomentosa</i> (Thunb.) Loisel. | |
| <i>Chaenoméles japonica</i> | |
| <i>Cotoneaster melanocarpus</i> Fisch. ex Blytt | |
| <i>C. lucidus</i> Schltld. | |
| <i>Cratégus douglasii</i> | |
| <i>C. laevigata</i> (Poir.) DC. | |
| <i>C. sanguinea</i> Pall. | |
| <i>Malus baccata</i> (L.) Borkh. | |
| <i>M. neidzwetzkyana</i> Dieck | |
| <i>M. 'Red Royalty'</i> | |
| <i>Padus avium</i> Mill. | |
| <i>P. maackii</i> (Rupr.) Kom | |
| <i>P. serotina</i> (Ehrh.) Borkh. | |
| <i>P. virginiana</i> (L.) Mill. | |
| <i>Physocarpus opulifolius</i> (L.) Maxim. | |
| <i>Ph. opulifolius</i> 'Dart's Gold' | |
| <i>Ph. opulifolius</i> 'Diabolo' | |
| <i>Prunus domestica</i> L. | Rosaceae |
| <i>P. spinosa</i> L. | |
| <i>Pyrus communis</i> L. | |
| <i>P. ussuriensis</i> Maxim. | |
| <i>Rosa acicularis</i> Lindl. | |
| <i>R. canina</i> L. | |
| <i>R. cinnamomea</i> L. | |
| <i>R. davurica</i> Pall. | |
| <i>R. rugosa</i> Thunb. | |
| <i>Rubus idaeus</i> L. | |
| <i>Sorbaria sorbifolia</i> (L.) A. Braun | |
| <i>Sorbus aucuparia</i> L. | |
| <i>Spiraea alba</i> Du Roi | |
| <i>Spiraea</i> × <i>billardii</i> Dippel | |
| <i>S. media</i> Schmidt | |
| <i>S. hypericifolia</i> L. | |
| <i>S. japonica</i> 'Little Princess' | |
| <i>S. japonica</i> 'Anthony Waterer' | |
| <i>S. japonica</i> 'Crispa' | |
| <i>S. japonica</i> 'Froebelii' | |
| <i>S. 'Gold Flame'</i> | |
| <i>S. japonica</i> 'Magic Carpet' | |
| <i>S. trilobata</i> L. | |
| <i>Berberis</i> × <i>ottawensis</i> | Berberidaceae |

| | |
|---|----------------|
| <i>B. integerrima</i> Bunge | |
| <i>B. sphaerocarpa</i> Kar. & Kir. | |
| <i>B. thunbergii</i> DC. | |
| <i>B. vulgaris</i> L. | |
| <i>Mahonia aquifolium</i> (Pursh) Nutt. | |
| <i>Betula kirghisorum</i> Sav. -Rycz. | |
| <i>B. pendula</i> Roth | |
| <i>B. pendula f. dalecarlica</i> (L. fill.) Schneid | |
| <i>B. pubescens</i> Ehrh. | Betulaceae |
| <i>B. tianschanica</i> Rupr. | |
| <i>Corylus avellana</i> L. | |
| <i>Caragana frutex</i> (L.) K. Koch | |
| <i>C. arborescens</i> 'Pendula' | |
| <i>C. frutex</i> (L.) K. Koch | |
| <i>Genista tinctoria</i> L. | Fabaceae |
| <i>Gleditsia triacanthos</i> L. | |
| <i>Robinia pseudoacacia</i> L. | |
| <i>Gymnocladus dioica</i> (L.) K. Koch | |
| <i>Elaeagnus angustifolia</i> L. | |
| <i>Hippophae rhamnoides</i> L. | Elaeagnaceae |
| <i>Shepherdia argentea</i> (Pursh) Nutt. | |
| <i>Euonymus europaeus</i> L. | Celastraceae |
| <i>Forsythia intermedia</i> Zabel | |
| <i>Fraxinus americana</i> L. | |
| <i>F. exelsior</i> 'Diversifolia' | |
| <i>F. pennsylvanica</i> Marshall | Oleaceae |
| <i>Syringa amurensis</i> Rupr. | |
| <i>S. josikaea</i> J. Jacq. ex Reichenb | |
| <i>S. vulgaris</i> L. | |
| <i>Juglans mandshurica</i> Maxim. | Juglandaceae |
| <i>J. regia</i> L. | |
| <i>Juniperus communis</i> . 'Hibernica' | |
| <i>J. horizontalis</i> 'Hughes' | |
| <i>J. pseudosabina</i> Fisch. & C.A. Mey. | |
| <i>J. pseudosabina</i> 'Albo Variegata' | |
| <i>J. chinensis</i> L. | |
| <i>J. x pfitzeriana</i> (Spath) P.A. Schmidt | Cupressaceae |
| <i>J. x pfitzeriana</i> 'Mint Julep' | |
| <i>J. sabina</i> L. | |
| <i>J. sabina</i> 'Glauca' | |
| <i>J. scopulorum</i> Sarg. | |
| <i>J. scopulorum</i> 'Sky Rocket' | |
| <i>Thuja occidentalis</i> L. | |
| <i>Lonicera caprifolium</i> L. | |
| <i>L. maackii</i> (Rupr.) Herder | Caprifoliaceae |
| <i>L. tatarica</i> L. | |
| <i>Symphoricarpos albus</i> (Fernald) S.F. Blake | |
| <i>Hydrangea paniculata</i> Siebold | |
| <i>Philadelphus coronarius</i> L. | Hydrangeaceae |
| <i>Ph. microphyllus</i> A. Gray | |
| <i>Populus alba</i> L. | |
| <i>P. balsamifera</i> L. | |
| <i>P. italica</i> (Du Roi) Moench | Salicaceae |
| <i>P. laurifolia</i> Ledeb. | |
| <i>P. x canescens</i> (Aiton) Sm. | |

| | |
|---|-----------------|
| <i>P. 'Kazakhstansky'</i> | |
| <i>P. nigra</i> L. | |
| <i>P. tremula</i> L. | |
| <i>Salix alba</i> L. | |
| <i>S. caprea</i> L. | |
| <i>S. × fragilis</i> L. | |
| <i>S. matsudana</i> Koidz. var. <i>Tortuosa</i> | |
| <i>S. purpurea</i> L. | |
| <i>S. viminalis</i> L. | |
| <i>Quercus macranthera</i> Fisch. et C.A. Mey. ex Hohen. | |
| <i>Q. robur</i> L. | Fagaceae |
| <i>Q. suber</i> L. | |
| <i>Ribes aureum</i> Pursh | Grossulariaceae |
| <i>R. nigrum</i> L. | |
| <i>Sambucus racemosa</i> L. | Sambucaceae |
| <i>Shepherdia argentea</i> (Pursh) Nutt. | Elaeagnaceae |
| <i>Swida alba</i> (L.) Opiz | Cornaceae |
| <i>Tamarix ramosissima</i> | Tamaricaceae |
| <i>Tilia americana</i> L. | |
| <i>T. cordata</i> Mill. | Malvaceae |
| <i>Frangula alnus</i> Mill. | Rhamnaceae |
| <i>Flueggea suffruticosa</i> (Pall.) Baill. | Phyllanthaceae |
| <i>Parthenocissus quinquefolia</i> (L.) Planch. | Vitaceae |
| <i>Ulmus glabra</i> Huds. | |
| <i>U. laevis</i> Pall. | Ulmaceae |
| <i>U. pumila</i> L. | |
| <i>Taxus cuspidata</i> Siebold & Zucc. | Taxaceae |
| <i>Viburnum lantana</i> L. | Viburnaceae |
| <i>V. opulus</i> L. | |
| <i>V. sargentii</i> Koehne | |
| Total: 140 species and 15 subspecies and varieties | |

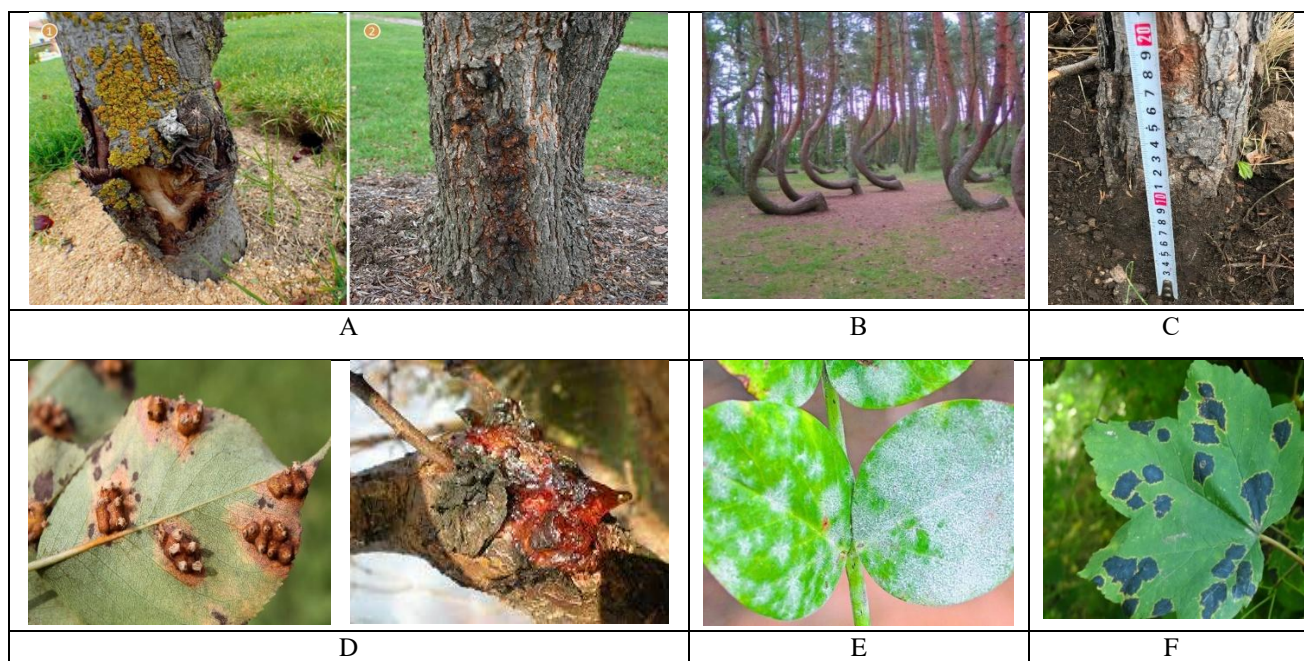


Fig. 8 A. butt rot of the trunk; B - deformations; C - buried root collar of *Pinus sylvestris* L.; D - pustules and gummosis with slime flux; E - coatings (powdery mildew, scab, etc.); F - necroses or dieback of plant tissues and organs.

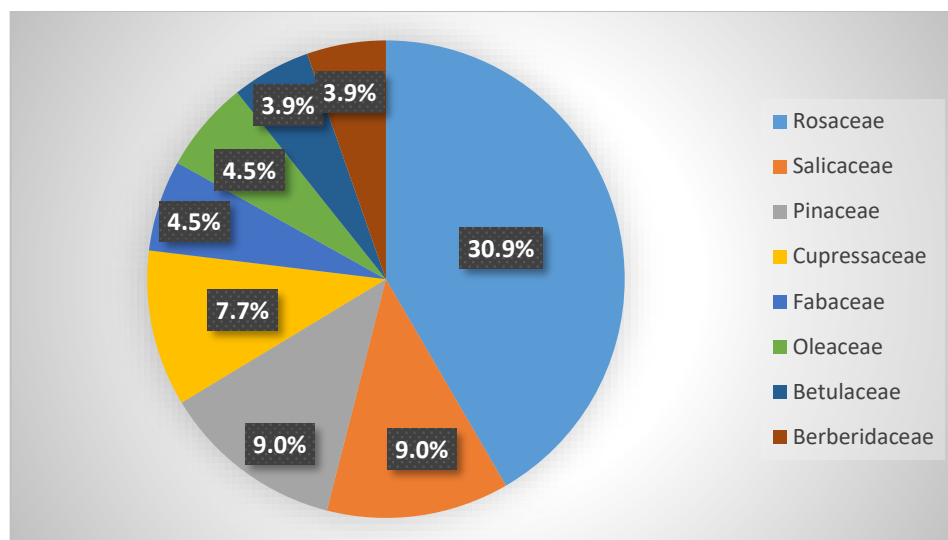


Fig. 9. Percentage share of leading families of tree and shrub plants in Astana.

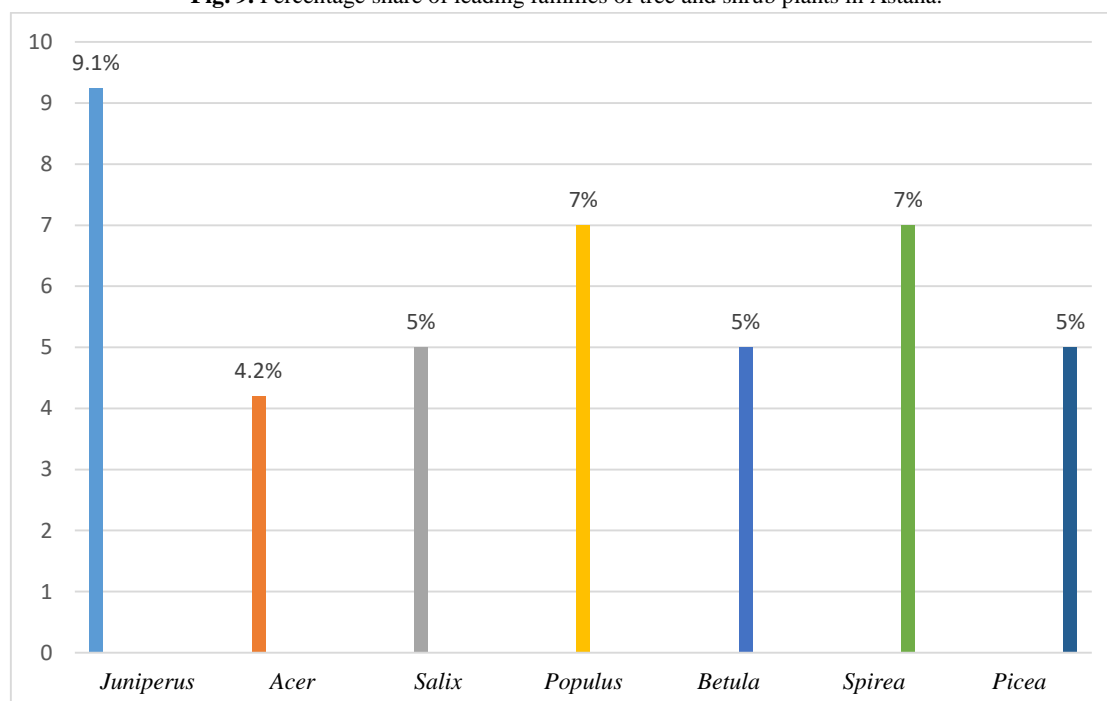


Fig. 10. Major genera of woody plants in the territory of the city of Astana.

DISCUSSION

The obtained results indicate that the green plantings of the city of Astana form a relatively stable but spatially heterogeneous system of urban dendroflora, the development of which is determined by a combination of natural-climatic conditions and features of urban planning. The high proportion of healthy plants (69.42%) indicates a generally satisfactory ecological condition of the green infrastructure, which is comparable to indicators recorded for other cities in the steppe and forest-steppe zones of Eurasia. The dominance of deciduous species (85.4%) corresponds to the general trend of urban landscaping under sharply continental climate conditions, where coniferous plants experience increased stress in winter associated with frost, wind erosion, and exposure to de-icing reagents. Similar patterns have been noted in studies of urban dendroflora of Pavlodar, Kostanay, and a number of cities in Northern Kazakhstan, where deciduous taxa demonstrate higher ecological plasticity and regenerative capacity. Pronounced differences between the administrative districts of Astana reflect the unequal history of green space formation. In new districts with planned development and systematic landscaping (Yesil and Almaty districts), more stable plantings are formed with a high proportion of plants in condition category I. In contrast, in districts with older development (Saryarka District), a significant proportion of overmature and

physiologically weakened plants remains, which is consistent with data from urban ecological studies indicating the critical role of planting age and maintenance level in shaping their vital condition. The taxonomic structure of Astana's urban dendroflora is characterized by dominance of a limited number of families and genera, primarily Rosaceae, Pinaceae, and Salicaceae. Such concentration of taxa is typical for urban ecosystems and is due to targeted selection of species with high ornamental value and resistance. At the same time, excessive reliance on a narrow range of plants increases the risk of mass damage in the event of pest outbreaks or pathogen spread, which is confirmed by the recorded foci of bacterial diseases and insect phytophage damage. The identified pest and disease species are mainly localized in weakened plantings, emphasizing the relationship between sanitary condition of plants and their phytosanitary resistance. The presence of entomophages indicates partial preservation of biological regulation mechanisms in the urban environment; however, the effectiveness of these processes is limited by fragmentation of green spaces and anthropogenic pressure. Analysis of species diversity of tree plantings in Astana using the Shannon index showed that in all districts of the city the level of diversity is assessed as moderate, typical for urbanized territories. The most stable and diverse structure is characteristic of the Yesil District. The Saryarka and Baikonur districts require expansion of the assortment of woody species, and increasing species evenness will enhance the ecological stability of the city's green plantings. The use of geoinformation technologies in this study made it possible to obtain a spatially detailed picture of the condition of green plantings and to identify problem areas requiring priority intervention. Unlike traditional inventory approaches, the GIS methodology ensures integration of quantitative, taxonomic, and ecological data, creating a basis for long-term monitoring and adaptive management of urban green infrastructure. Thus, the obtained results supplement existing knowledge on the formation and functioning of urban dendroflora under sharply continental climate conditions and emphasize the need to shift from quantitative expansion of green plantings to their qualitative optimization, taking into account sustainability, taxonomic diversity, and spatial structure.

CONCLUSION

As a result of the conducted study, a comprehensive inventory of urban green plantings in Astana was carried out using geoinformation technologies, which made it possible to obtain detailed and spatially structured information on the condition and taxonomic composition of the urban dendroflora. It was established that 1,345,872 specimens of tree and shrub plants grow within the city, represented by 155 species, forms, and cultivars belonging to 61 genera and 27 families. The taxonomic structure is dominated by representatives of the families Rosaceae, Pinaceae, and Salicaceae, and in terms of life forms deciduous plants prevail (85.4%), reflecting adaptation of the assortment of green plantings to sharply continental climate conditions. Analysis of species diversity of tree and shrub plantings using the Shannon index revealed significant differences between districts. The highest species diversity is characteristic of the Yesil District ($H' = 3.3$), indicating high ecological stability of the plantings. The minimum Shannon index values were recorded in the Baikonur District ($H' = 2.4$), indicating a more homogeneous structure of plantings and the need to optimize species composition. Sanitary assessment showed that 69.42% of the recorded plants belong to condition category I, which generally indicates a satisfactory ecological condition of the city's green infrastructure. At the same time, pronounced spatial heterogeneity of plant vitality was identified, determined by planting age, building density, traffic load, and maintenance intensity. The most problematic areas are concentrated in districts with older development and high anthropogenic pressure. Analysis of phytosanitary condition revealed focal distribution of insect pests and bacterial diseases, predominantly in weakened plantings. The presence of entomophages indicates partial preservation of biological regulation mechanisms; however, their effectiveness under urban conditions remains limited. The use of GIS technologies demonstrated high efficiency for inventory, analysis, and monitoring of green plantings, providing a scientific basis for managerial decision-making in the field of urban landscaping. The obtained results supplement existing data on the functioning of urban vegetation under sharply continental climate conditions and can be used in the development of strategies for sustainable development of urban green infrastructure.

Practical Recommendations

Based on the obtained results, it is proposed to:

Optimize the species composition of urban plantings by expanding the assortment of tree and shrub species resistant to climatic and anthropogenic stresses, in order to reduce the risk of biological homogenization of dendroflora.

Prioritize reconstruction of plantings in districts with a high proportion of weakened and dying plants, primarily in the Saryarka District and along major highways.

Introduce regular GIS-based monitoring of the condition of green plantings as a tool for long-term control and prompt identification of problem areas.

Strengthen phytosanitary control using preventive and biological plant protection methods, minimizing the use of chemical agents.

Take into account the spatial structure of landscaping when planning new residential and public areas, forming an ecologically connected system of green corridors.

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Bibliographic information of this paper for citing:

Berkinbayev, G, Mukhtubayeva, S, Zhanseit, F, Borissova, Y, Zhamangara, A, Koblanova, S, Koibagarova, G, Kurmanova, A 2026, Ecological status and taxonomic diversity of urban green plantings of Astana, Kazakhstan. *Caspian Journal of Environmental Sciences*, 24: 47-61.
