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ECOLOGICAL QUALITY OF SCHOOL GREEN SPACES: A CASE STUDY FROM ZHYTOMYR CITY (NORTHERN UKRAINE)

Markov F.F. *– Candidate of Agricultural Sciences,*
Associate Professor at the Department of Forestry and Horticulture,
Polissia National University
orcid.org/0000-0002-6482-8558

Zymaroieva A.A. *– Doctor of Agricultural Sciences,*
Associate Professor at the Department of Botany, Ecology, and Horticulture,
Bogdan Khmelnytskyi Melitopol State Pedagogical University
orcid.org/0000-0001-9382-8269

Pitsil A.O. *– Candidate of Agricultural Sciences,*
Associate Professor at the Department of Ecology,
Polissia National University
orcid.org/0000-0002-0962-574X

Hroshev Ya.A. *– PhD student,*
Department of Botany, Ecology, and Horticulture,
Bogdan Khmelnytskyi Melitopol State Pedagogical University
orcid.org/0009-0004-0522-7586

Zymaroiev O.O. *– PhD student,*
Department of Botany, Ecology, and Horticulture,
Bogdan Khmelnytskyi Melitopol State Pedagogical University
orcid.org/0009-0008-8344-5473

Urban school grounds represent important but often underestimated elements of green infrastructure, contributing to biodiversity conservation, ecosystem services, and the well-being of children. This study assessed the greening level, species composition, and ecological characteristics of woody vegetation on the territories of educational institutions in Zhytomyr City and the village of Veresy (northern Ukraine). A total of 36 schools were analyzed using spatial data on total area, green space coverage, and field-based dendrological inventories. Greening levels were evaluated in accordance with national standards, while species diversity, life forms, geographic origin, ecological requirements, and functional traits were also examined. The results revealed a highly uneven distribution of green space, with 50% of schools failing to meet the standard greening threshold of 45–50%. Only 30 species of trees and shrubs belonging to 26 genera and 16 families were recorded, indicating low taxonomic diversity and a strong dominance of a few families, primarily Rosaceae and Pinaceae. The dendroflora was largely composed of native, mesophytic, deciduous species, with limited representation of evergreen, drought-tolerant, and salt-tolerant taxa. Introduced species constituted a minor fraction, while invasive species were scarce but included ecologically impactful taxa such as Robinia pseudoacacia. Functional analysis highlighted potential vulnerabilities related to climate change, urban stressors, and insufficient ecological resilience of current plantings. Overall, the *findings demonstrate that many school grounds lack adequate green coverage and functional diversity, underscoring the need for targeted greening and diversification strategies. The study provides a baseline for enhancing schoolyard landscaping by integrating ecologically resilient, functionally diverse, and health-promoting plant species, thereby supporting sustainable urban development and educational environments.*

Key words: *school grounds, urban green spaces, dendroflora, species diversity, ecological traits, urban resilience, green infrastructure, Ukraine.*

Марков Ф.Ф., Зимароєва АА., Пініль А.О., Грошев Я.А., Зимароєв О.О. Екологічна якість зелених насаджень шкіл: приклад міста Житомир (Північна Україна)

Території міських закладів освіти є важливими, але часто недооціненими елементами зеленої інфраструктури, що сприяють збереженню біорізноманіття, наданню екосистемних послуг і покращенню добробуту дітей. У дослідженні оцінено рівень озеленення, видовий склад та екологічні характеристики деревно-чагарникової рослинності на територіях закладів освіти м. Житомира та с. Вереси (північ України). Проаналізовано 36 шкіл із використанням просторових даних про загальну площу, площу зелених насаджень та результатів польових дендрологічних обстежень. Рівень озеленення оцінювали відповідно до національних нормативів; також проаналізовано різноманіття видів, життєві форми, географічне походження, екологічні вимоги та функціональні ознаки рослин. Результати засвідчили значну нерівномірність розподілу зелених насаджень: 50% шкіл не відповідають нормативному рівню озеленення 45–50%. Виявлено лише 30 видів дерев і кущів, що належать до 26 родів і 16 родин, що свідчить про низьке таксономічне різноманіття та домінування небагатьох родин, передусім Rosaceae і Pinaceae. Дендрофлора переважно представлена аборигенними, мезофітними, листяними видами, з обмеженою часткою вічнозелених, посухо– та солестійких таксонів. Інтродуковані види становлять незначну частку, а інвазійні види трапляються рідко, хоча серед них є екологічно значущі таксони, зокрема Robinia pseudoacacia. Функціональний аналіз виявив потенційні вразливості, пов'язані зі зміною клімату, урбаністичними стресорами та недостатньою екологічною стійкістю існуючих насаджень. Загалом результати свідчать, що значна частина шкільних територій має недостатній рівень озеленення та обмежене функціональне різноманіття, що підкреслює необхідність цілеспрямованих стратегій озеленення та збагачення видового складу. Дослідження формує базу для вдосконалення шкільного ландшафтного озеленення шляхом інтеграції екологічно стійких, функціонально різноманітних і здоров'я-орієнтованих видів рослин, сприяючи сталому розвитку міст і покращенню освітнього середовища.

Ключові слова: *шкільні території міські зелені насадження, дендрофлора, видове різноманіття, екологічні ознаки, урбаністична стійкість, зелена інфраструктура, Україна.*

Relevance of the research topic. Urban green spaces play a crucial role in maintaining ecological balance, supporting biodiversity, and improving environmental quality and human well-being, particularly within densely populated settlements [1, 2]. Among various types of urban green infrastructure, the territories of educational institutions represent a specific and socially significant category. School grounds not only contribute to urban ecological networks but also directly influence children's physical and mental health, environmental education, and everyday contact with nature [3, 4]. However, despite their importance, school green spaces remain insufficiently studied in many Eastern European cities, especially in terms of their quantitative provision, species composition, and ecological functionality.

In Ukraine, regulatory documents establish clear requirements for the proportion of green spaces within school territories, recommending that 45–50% of the total area of general secondary schools should be occupied by greenery [5]. In practice, however, urban densification, aging infrastructure, and limited funding for maintenance often lead to deviations from these standards. Previous studies have indicated that insufficient greening of schoolyards can exacerbate urban heat stress, reduce air quality, and limit ecosystem services, such as dust retention, noise reduction, and microclimate regulation [5].

Beyond the total area of green spaces, the ecological effectiveness of school plantings largely depends on their species diversity, structural complexity, and functional traits. Low taxonomic and functional diversity, often resulting from the repeated use of a limited number of common tree species, can reduce the resilience of plantings to pests, diseases, climate extremes, and other urban stressors [6]. Conversely, a well-balanced assortment of species differing in life forms, crown architecture, ecological requirements, and stress tolerance enhances ecosystem stability and multifunctionality [18].

Urban trees are simultaneously exposed to multiple environmental pressures, including soil compaction, altered hydrology, air pollution, soil salinization due to de-icing salts, and increasing frequency of droughts associated with climate change [7]. Therefore, assessing species traits such as drought tolerance, winter hardiness, pollution resistance, and salt tolerance is essential for evaluating the long-term sustainability of urban plantings [8]. In this context, the dominance of mesophytic, salt-sensitive, or thermophilic species may indicate hidden vulnerabilities of green infrastructure, particularly under future climate scenarios [9].

Another important yet often overlooked function of school greenery is its role in sanitation and hygiene. Many woody plants release phytoncides (biologically active volatile compounds that can suppress pathogenic microorganisms in the air), which can improve air quality and potentially reduce respiratory infections among children [27]. Thus, the selection of phytoncidic species has direct implications for public health in educational environments.

Problem statement. Despite the recognized ecological, social, and hygienic importance of school green spaces, insufficient attention has been paid to their actual provision, species composition, ecological structure, and functional characteristics in Ukrainian urban environments. In particular, there remains a lack of comprehensive studies assessing whether school territories comply with national greening standards and whether their woody plantings are capable of ensuring ecological stability, environmental resilience, and the delivery of key ecosystem services under current urban and climatic pressures.

Against this background, the present study aims to provide a comprehensive assessment of greening levels and dendrofloristic characteristics of school territories in the city of Zhytomyr and the nearby village of Veresy. Specifically, the study evaluates (1) compliance of school grounds with national greening standards, (2) taxonomic and ecological structure of woody plantings, (3) functional traits related to environmental tolerance and ecosystem services, and (4) the overall condition of trees. By integrating spatial analysis, floristic inventory, and functional assessment, this work seeks to identify key weaknesses and opportunities for improving the ecological performance and sustainability of school green spaces. The results aim to provide a scientific basis for urban planning, educational policy, and future greening initiatives in Ukrainian cities and similar urban contexts.

Materials and methods of research. This study analyzes the greening levels of educational institution territories in the city of Zhytomyr and the village of Veresy using a consolidated dataset on total land areas, green space areas, and their percentages. A total of 36 general secondary education institutions (GSEI) were analyzed.

To systematize the results for cartographic visualization, greening levels were classified according to the standards set out in Annex 5 to Section 15 of the "Rules for the Maintenance of Green Spaces in Settlements of Ukraine" [10]. Based on these requirements, the following categories were established:

– Critically Low Level (< 25%) – An indicator nearly twice as low as the established state standard.

– Insufficient Level (25–44%) – Institutions that fail to meet the mandatory minimum greening requirement.

– Meets Standard (45–55%) The range that fully complies with the requirements of Annex 5 to Section 15 of the Rules.

– High Level (> 55%)– An indicator significantly exceeding the standard, ensuring high ecological and climate resilience.

The inventory of dendroflora was conducted in accordance with the approved instructions [11]. The nomenclature of species, subspecies, and hybrids followed the World Checklist of Vascular Plants [12]. The distribution of trees was categorized according to ecological scales, following Ellenberg [13]. The geographical origin of plants was assessed using the scheme of H. Meusel [14]. Air Pollution Tolerance Index (APTI) was used to assess resistance to anthropogenic emissions [15]. The ornamental value of trees was assessed by analysing their morphological characteristics, including crown structure, trunk shape and texture, plant height, branch arrangement, shape, surface structure, and leaf colour.

Research results. Spatial analysis showed an uneven distribution of schools across green zones (Fig. 1). The largest number of schools with both high and low levels of greenery are located in the city's central part.

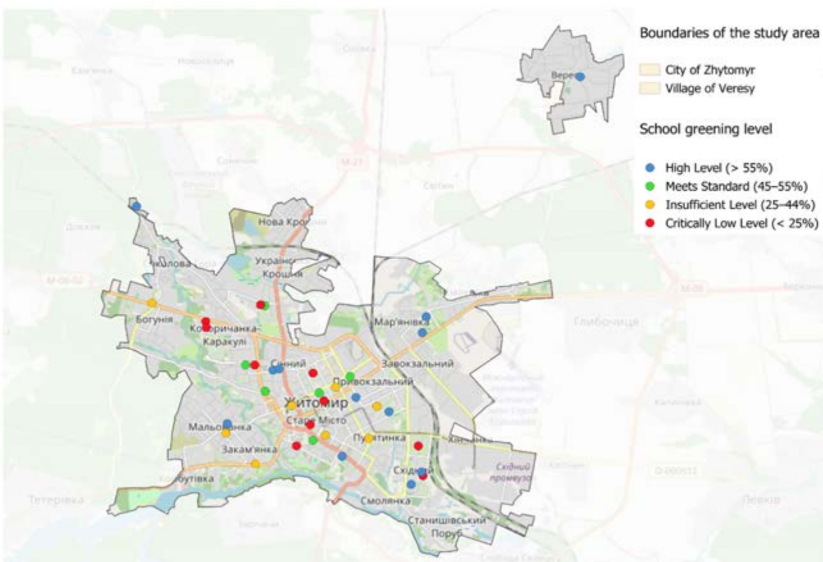

Fig. 1. Spatial distribution of greening levels of secondary school territories in Zhytomyr and the Village of Veresy

According to the regulations for the maintenance of green spaces in settlements of Ukraine, the greening level for general secondary school sites must be 45–50% [10]. The High Level group (> 55%) includes 12 institutions (33% of the total). The leaders are Lyceum No. 15 (89.4%) and Lyceum No. 10 (85.8%). This group also includes the Veresivskyi Lyceum (61.6%) and Lyceum No. 31 (72.8%). The Meets Standard category (45–55%) counts 6 schools (17%). This includes Lyceum No. 8 (54.6%), the Youth Sports School (51.2%), and Lyceum No. 6 (47.7%), demonstrating a proper balance between built-up areas and vegetation. Meanwhile, half of the surveyed institutions (18 schools) violate the established greening standards: The Insufficient Level category (25–44%) consists of 8 institutions (22%), including Lyceum No. 34 (40.9%) and Lyceum No. 1 (39.2%). Of greatest concern is the Critically Low Level group (< 25%), which includes 10 institutions (28%). These schools suffer from a critical deficit of green zones, contradicting the current Rules for the Maintenance of Green Spaces. The lowest values were recorded at Lyceum No. 17 (5.5%) and Lyceum No. 30 (6.2%). The findings highlight the urgent need for revitalization programs for school grounds in 50% of the community's institutions to bring them into compliance with national environmental standards.

The inventory revealed that the school grounds in Zhytomyr host only 30 species of woody plants, belonging to 26 genera and 16 families (Table 1). This indicates a relatively low species diversity of the greenery, as a limited set of taxa is used for plantings.

Table 1

Quantitative Taxonomic Structure of the Dendroflora of the Studied Parks

Family	**Taxonomic Unit**		
	genus	**species**	**cultivar, hybrid**
	quantity, units	**quantity, units**	**quantity, units**
Pinophyta			
Pinaceae	4	4	–
Cupressaceae	1	1	–
Magnoliophyta			
Aceraceae	1	2	–
Anacardiaceae	1	1	–
Betulaceae	2	2	–
Bignoniaceae	1	1	–
Fabaceae	1	1	–
Fagaceae	1	1	–
Hippocastanaceae	1	1	–
Juglandaceae	1	1	–
Oleaceae	1	1	–
Rosaceae	6	8	–
Salicaceae	2	3	–
Tiliaceae	1	1	–
Ulmaceae	1	1	–
Ginkgoaceae	1	1	–
Total	26	30	–

The family Rosaceae is the most represented, with 8 species (mostly fruit and ornamental Prunus and Malus), accounting for over one-quarter of all species. Conifers of the Pinaceae family also contribute notably (4 species representing *Pinus, Picea*, *Abies*, and *Larix*), whereas most other families are represented by only one or two species each. The dominance of a few families, largely comprising common fruit trees and widespread native species, points to a certain uniformity in the plantings. On one hand, these species are well-known and easy to maintain; on the other hand, low taxonomic diversity can reduce the stands' resilience to pests and diseases (due to monoculture effects) and limit the ornamental value of the green zones [16]. Thus, there is a need to enrich the species composition by introducing new taxa, which would enhance biodiversity and improve the ecological stability of the plantings.

An analysis of the life forms of the woody plants showed a sharp dominance of deciduous species. Of the 30 recorded species, only 5 (≈17%) are evergreen trees (conifers from the families Pinaceae and Cupressaceae), whereas the remaining 25 species (≈83%) are deciduous (Table 2).

Table 2

Quantitative Distribution of Dendroflora Species of Secondary Schools by Life Forms

Life form	Number of species, cultivars, hybrids, units	% of the total amount
Evergreen trees	5	17
Deciduous trees	25	83
Total	30	100

This structure of green areas with a predominance of deciduous species is typical for urban plantings; however, it has drawbacks. In particular, the limited proportion of evergreens means that schoolyards almost completely lose their foliage cover during the autumn-winter period. This reduces the decorative appeal of the grounds and diminishes certain protective functions (e.g., dust capture, noise abatement) in the cold season [17]. The existing evergreens (thuja, spruce, pine, etc.) provide some structural greenery in winter, but their number is clearly insufficient. Therefore, increasing the share of evergreens in the species mix is advisable, as it would improve year-round visual attractiveness and ecological functionality of the plantings [18].

In terms of growth form and size, the plantings are primarily composed of medium– to tall-sized trees. Most species are large trees of the first or second size class (canopy height >10 – 15 m), though the dendroflora does include a few smaller trees/shrubs (e.g., *Rhus typhina* and *Catalpa bignonioides*). The presence of trees of various heights contributes to the vertical structure and stratification of the greenery. This vertical structure provides diverse habitats for wildlife and contributes to overall ecosystem complexity and biodiversity [19].

Examining the geographic origin of the species composition shows a predominance of native and broadly distributed temperate-zone species (Table 3).

Table 3

Distribution of dendroflora species in General Secondary Education Institutions by floristic regions

No.	Name of floristic region	Number of species, units
1	Circumboreal	13
2	Atlantic-North American	3
3	East Asian	2
4	Irano-Turanian	1
5	Rocky Mountain region	-
6	Ranges covering multiple regions	9
7	Origin unknown	2
Total		30

The largest group of species (13, about 43%) belongs to the Circumboreal floristic region, i.e., elements of the Northern Hemisphere flora, including those indigenous to Polissia (northern Ukraine). This group comprises English oak (*Quercus robur*), silver birch (*Betula pendula*), Scots pine (*Pinus sylvestris*), small-leaved linden (*Tilia cordata*), and other local taxa well-adapted to the regional climate. A substantial portion of the species (9 species, ~30%) have ranges spanning multiple floristic regions. These include broadly distributed Eurasian species such as European ash (*Fraxinus excelsior*), wych elm (*Ulmus glabra*), white willow (*Salix alba*), and aspen (*Populus tremula*). Such species occur naturally across Europe and parts of Asia, indicating their adaptability to local conditions.

Introduced (exotic) species make up a relatively small fraction of the dendroflora – roughly 26–30% of the total (8–9 species). Among them are North American species (3 species, e.g. *Robinia pseudoacacia, Thuja occidentalis, Catalpa bignonioides*) and East Asian species (2 species, e.g. *Armeniaca vulgaris* (apricot), *Ginkgo biloba*). One species has an Irano-Turanian origin (*Juglans regia, Persian walnut*). Two introduced species are cultivated hybrids of unclear wild origin (*Malus domestica, Prunus domestica*). The limited presence of introduced species indicates that school landscaping relies mainly on native taxa, which ensures good acclimation of plants. On the other hand, it misses the opportunity to increase biodiversity through hardy exotics. It is known that some introduced species can possess unique ornamental qualities and high adaptability in urban environments [20]. Therefore, it may be worth considering the incorporation of new, promising tree species into school plantings – especially those proven to be resilient under current climate change conditions (drought-tolerant, cold-hardy, pest-resistant, etc.) [21].

Invasive alien species are only a minor component of the plantings. We identified two tree species considered invasive in Ukraine – *Robinia pseudoacacia* (black locust) and *Rhus typhina* (staghorn sumac) – comprising about 6.7% of the total species count. Black locust is a widely distributed introducent capable of self-seeding and outcompeting native flora; its relatively high abundance in the schools (58 individuals recorded) may pose ecological risks [22]. Sumac occurs sparsely (32 individuals in total) and, although it can spread vegetatively, it is not currently dominant. The very low representation of invasives is a positive aspect, as it minimizes the threat of biological invasions on school grounds. Nonetheless, attention should be paid to controlling the spread of black locust to prevent prolific self-seeding and the suppression of other plants.

With respect to soil moisture preferences, the school dendroflora is composed almost entirely of mesophytes (Figure 2). The majority of species (90%) are mesophytic, i.e., plants that require moderate moisture levels. Only one species (the catalpa) is classified as a xerophyte (drought-tolerant), which is about 4% of the total. This extremely low share of xerophytic species indicates a potentially low overall drought tolerance of the current plantings [23]. In the event of more frequent summer droughts in the region, this could become problematic: mesophytic trees (e.g., linden, maple, spruce) will experience water stress without supplemental irrigation [24].

Conversely, truly drought-resilient species are virtually absent, suggesting that future species selections should include more drought-tolerant taxa. A small proportion of hygrophytic, water-loving species (6%, e.g., white willow and black poplar) are present, adapted to very moist habitats. Their presence suggests that some plantings were selected for wet areas (perhaps those with high groundwater levels or near drainage sites). However, the dominance of mesophytes suggests that, overall, soil moisture conditions on school grounds are moderate, without extreme wet or arid conditions.

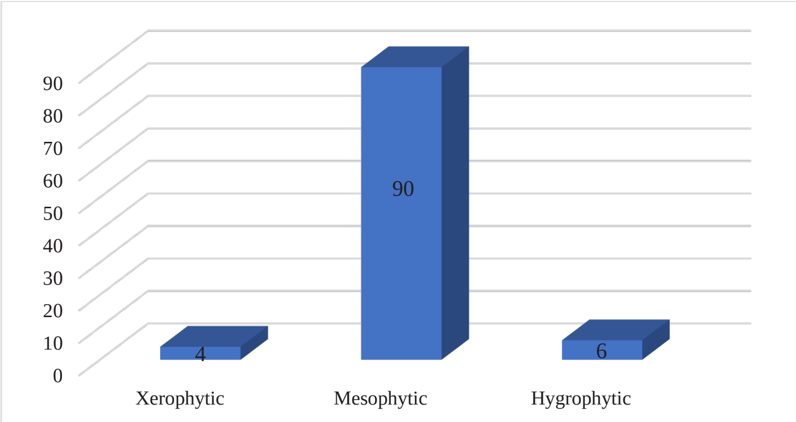

Fig. 2. Distribution of woody plants in general secondary education institutions (GSEI) by moisture requirements, % of the total number of specimens

According to soil fertility requirements (Fig. 3), mesotrophic species (plants requiring moderate soil fertility) and oligotrophic species (undemanding plants) predominate. The presence of a substantial proportion of oligotrophic species (approximately 43% of the total number of species, including transitional forms) is a positive factor for urban environments, where soils are often represented by urban soils (urbanozems) – compacted substrates with disturbed structure and inclusions of construction debris. Oligotrophic species, such as *Pinus sylvestris* and *Betula pendula*, are capable of surviving on nutrient-poor soils. Megatrophic species (highly demanding in terms of soil fertility), including *Juglans regia* and *Acer platanoides*, account for about 30%. Their successful growth indicates that relatively intact humus horizons have likely been preserved within school territories or that fertile soil has been artificially introduced.

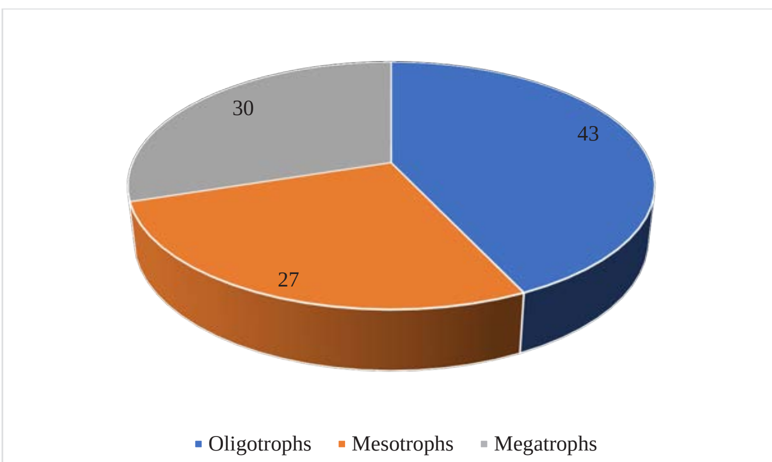

Fig. 3. Distribution of woody plants in GSEI by soil fertility requirements, % of the total number of specimens

One key aspect of adaptability is the species' winter hardiness. Over half (53%) of the school dendroflora species are winter-hardy (high cold tolerance), meaning they can withstand the low temperatures typical of the region. This group includes both native species (oak, pine, birch) and certain introduced ones known for their hardiness (*Thuja occidentalis*, *Picea abies*, etc.). Approximately 10% of the species (three species) are relatively winter-hardy, they tolerate average winters but may suffer damage in extreme cold or late frosts (for example, *Aesculus hippocastanum*). In contrast, 11 species (37%) were classified as thermophilic, with low frost resistance (Fig. 4). These include *Juglans regia, Catalpa bignonioides*, several fruit trees (*Malus domestica, Prunus domestica, Armeniaca vulgaris*), and ornamental sakura – all originating from regions with milder climates or warmer southerly areas. Incorporating such heat-loving plants into landscaping carries some risk: during severe cold spells or harsh winters, they could sustain significant frost damage or even die. The high percentage of thermophilic species suggests that the current species mix was selected without full consideration of potential cold extremes.

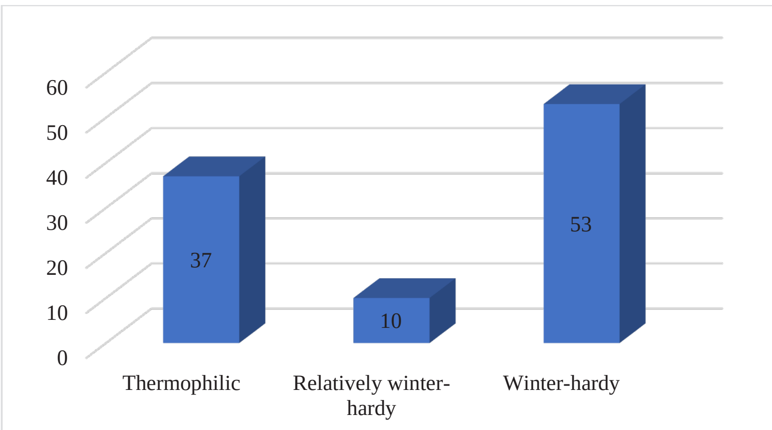

Fig. 4. Quantitative distribution of dendroflora species in GSEIs by degree of winter hardiness: 1 – winter-hardy, 2 – relatively winter-hardy, 3 – thermophilic

Given the overall warming trend in the climate of Polissia [22], many of these thermophiles are currently growing successfully. However, in the event of unpredictable anomalies (a sudden cold snap or an unusually severe winter), there could be widespread injury to these trees. Therefore, future landscaping should aim to balance the assortment with more cold-hardy species, selecting well-adapted native trees or proven hardy exotics.

In terms of air pollution tolerance, it was found that the majority (~63%) of species are relatively resistant to urban air pollutants and exhaust gases. Gas-tolerant species include *Tilia cordata, Robinia pseudoacacia, Betula pendula, Sorbus aucuparia, Catalpa bignonioides*, and others that can withstand polluted air without serious foliar damage. Their high proportion is a positive attribute, since in an urban environment (even around schools), the level of vehicular and industrial air pollutants can be significant. Conversely, about 37% of species are sensitive to air pollution – among them *Acer platanoides, Picea abies, Aesculus hippocastanum, Pinus sylvestris, Quercus robur,* and a few others. These trees may become stunted or exhibit leaf injuries (necrotic spots, chlorosis) under heavy pollution [25]. While school grounds typically experience lower pollution than city centers, sensitive species planted near parking lots or busy roads could be at risk. In general, the present species assemblage is fairly well-suited to the urban atmospheric conditions, but increasing the proportion of highly pollution-tolerant species could further strengthen the resilience of the plantings.

Analysis of salt tolerance (resistance to soil salinity) indicates that only about one-quarter of the species (~27%) can tolerate elevated salt levels in the soil. Salt-tolerant species include *Pyrus communis, Sorbus aucuparia, Juglans regia, Picea abies, Cerasus vulgaris* (sour cherry), *Prunus divaricata* (cherry plum), *Salix alba*, and *Robinia pseudoacacia.* These species better withstand the presence of de-icing salts (chlorides, sodium) in the soil during winter. In contrast, the majority (~73%) are salt-sensitive – including linden, Norway maple, horse chestnut, birch, ash, Scots pine, ginkgo, and others. Even moderate soil salinity can cause growth suppression, leaf burn, and decline in these species [26]. On school grounds, salinization issues may occur along walkways and sidewalks that are treated with salt during winter. The identified imbalance (predominance of salt-sensitive species) means that either the use of salt on planted areas should be minimized or more salt-tolerant trees should be planted in high-risk zones.

A notable positive characteristic of the school plantings is their phytoxicidal activity. It was determined that 18 out of 30 species (60%) are phytoncidic, meaning they release biologically active volatile compounds that suppress airborne pathogenic microorganisms. The most strongly phytoncidic species in the school dendroflora include oak, ash, birch, elm, pine, fir, hornbeam, linden, walnut, and locust. The substantial proportion of such trees improves the sanitary and hygienic condition of the air in the school environment. Volatile phytoncides from conifers and certain broadleaf trees are known to reduce airborne bacteria and viruses [27], which is especially beneficial in areas frequented by children. Thus, the existing plantings fulfill not only aesthetic but also health-promoting functions, helping to disinfect the air and potentially reducing respiratory infections [28]. At the same time, nearly 40% of the species (mainly fruit trees like apple, plum, cherry, as well as exotics like catalpa and sumac) do not exhibit notable phytoncidal properties. When renewing plantings, it would be prudent to give preference to highly phytoncidic species, considering their contribution to a healthier microenvironment.

Analysis of the quantitative distribution of trees by light preference (Fig. 5) shows that 44% of species are light-demanding, 33% are shade-tolerant, and 23% are moderately shade-tolerant. This distribution reflects a dominance of species requiring ample sunlight. Among the light-demanding trees are *Acer platanoides, Quercus robur*, and *Robinia pseudoacacia*, which thrive in open, unshaded areas with maximum solar exposure. Under such conditions, these trees demonstrate rapid growth and strong ornamental value. However, school grounds typically include shaded areas near buildings, internal courtyards, or fences. In these zones, light-demanding species may underperform, exhibit reduced growth, or develop asymmetrical canopies. The presence of moderately shade-tolerant (23%) and fully shade-tolerant (33%) trees helps to partially compensate for these limitations by enabling greening in less favorable microclimatic conditions. The existing proportions suggest an overall acceptable level of ecological differentiation, though the prevalence of light-demanding trees (over 40%) requires careful spatial planning. This is particularly important for shaded locations, where species such as *Tilia cordata*, *Acer campestre*, or *Carpinus betulus* are better suited.

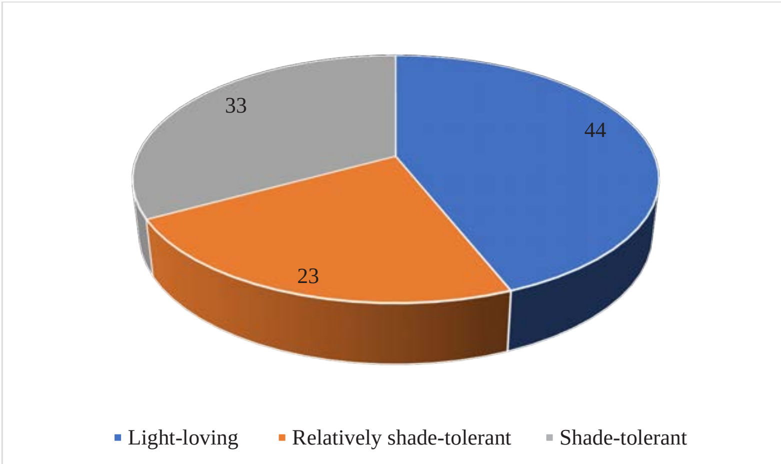

Fig. 5. Quantitative distribution spectrum of dendroflora species in GSEIs by light requirements: 1 – light-loving, 2 – relatively shade-tolerant, 3 – shade-tolerant

The species composition revealed a wide range of crown shapes, which enhances the landscape diversity of the plantings. The majority of species have egg-shaped and spreading crown forms (6 species each, or 20% of the total) (Table 4). These include, in particular, rowan, cherry, and hornbeam (egg-shaped crowns), as well as walnut, plum, and ash (spreading crowns). Several species form conical crowns (4 species, 13.3%) or rounded crowns (also 4 species, 13.3%), which add geometric structure to the overall silhouette of the greenery. Less common forms include pyramidal (2 species), openwork (3 species), tent-like (2 species), umbrella-shaped, and columnar crowns (1 species each), which create focal accents in the landscaping. Overall, the architectural diversity of crowns contributes to a multilayered and varied school landscape. However, it should be noted that specialized cultivars with ornamental crown features (e.g., weeping, espaliered, and dwarf forms) are virtually absent, limiting the possibilities for aesthetic design.

The foliage (or needles) color of most woody plants encompasses the full range of green shades. Dark green foliage is observed in 46.7% of species (spruce, hornbeam, fir), light green in 23.3%, pale green in 16.7%, and green in 13.3%. Thus, the summer greenery presents a harmonious natural appearance. At the same time, species with purple, yellow, or variegated leaves are completely absent, narrowing the decorative palette. To enhance seasonal visual appeal, it is advisable to incorporate cultivars with non-standard foliage coloration, particularly during the spring and autumn seasons.

Regarding flowering, only one-third of the species (33.3%) exhibit pronounced ornamental value during blooming: 6.7% of species have pink flowers (sakura, almond), 10% – white-pink (apple, apricot), and 16.7% – white (black locust, hawthorn). The remaining species (66.7%) have inconspicuous or greenish flowers, including yellow-green, brown-green, dark green, green-yellow, and white-green, which do not create a strong decorative effect. As such, schoolyard landscaping in spring is characterized by moderate aesthetic activity. To enhance this, it is recommended to expand the range of tree species by incorporating decorative flowering varieties, such as ornamental

Table 4

Characteristics of Ornamental Features of Tree and Shrub Species in General Secondary Education Institutions

Ornamental feature	Number of coniferous species	Number of deciduous species	total	% of total
By Crown Shape:				
Pyramidal	1	1	2	6,7
Openwork (lacy)	1	2	3	10,0
Conical	3	1	4	13,3
Rounded		4	4	13,3
Oval		1	1	3,3
Egg-shaped		6	6	20,0
Umbrella-shaped		1	1	3,3
Tent-shaped		2	2	6,7
Spreading		6	6	20,0
Columnar		1	1	3,3
Total:	5	25	30	100
By Leaf (Needle) Color:				
Dark green	2	12	14	46,7
Green	1	3	4	13,3
Light green		5	5	16,7
Pale green	2	5	7	23,3
Total:	5	25	30	100
By Flower Color:				
Yellow-Green	1	4	5	16,7
Yellow-Red	1		1	3,3
Yellow	2		2	6,7
Yellow-White		1	1	3,3
Green-Yellow		2	2	6,7
Dark Green		1	1	3,3
Red		1	1	3,3
Red-Green		2	2	6,7
White		5	5	16,7
White-Green		1	1	3,3
White-Pink		3	3	10,0
Brown-Green		1	1	3,3
Green	1	2	3	10,0
Pink		2	2	6,7
Total:				100

apple trees, sakura, catalpas, and chestnuts, while ensuring their adaptability to the local microclimate [29, 30].

Schoolyard landscaping demonstrates high morphological and color diversity, yet its ornamental expressiveness requires improvement. It is recommended to increase the share of species with unusual crown shapes, brightly coloured foliage, and showy flowers, focusing on seasonal attractiveness, biological resilience, and adaptation to urban conditions.

Assessment of the trees' condition on the school grounds showed that they are predominantly in fair (satisfactory) health (Fig. 6). Out of 2,089 surveyed trees, only 169 specimens (~8%) were rated to be in good condition, with dense crowns and no signs of decline or significant damage. The majority – 1,854 trees (~89%) – were assessed as fair: these trees are surviving and functional, but exhibit some minor issues (e.g., a few dead branches, reduced growth vigor, or isolated pest/disease damage). This distribution suggests that the majority of the greenery is functioning properly, although not in optimal condition. Additionally, 66 trees (~3%) were found to be in poor condition, showing very sparse crowns, numerous dead limbs, or clear symptoms of severe disease or injury. Such specimens pose potential hazards (e.g., branchfall) and have low ornamental value, thus requiring remedial action or removal [10].

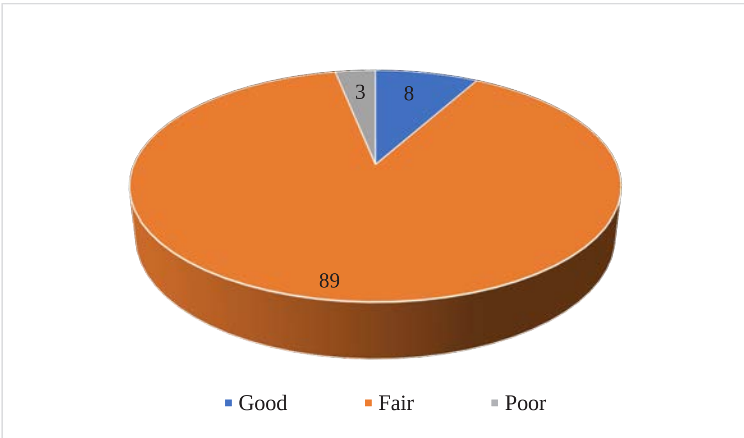

Fig. 6. Distribution of tree plantings in general secondary education institutions by viability

The predominance of trees in fair condition is likely due to a lack of intensive care, the impact of urban stress factors, and the age structure of the plantings [6]. Many trees were planted decades ago and have reached maturity, at which point growth naturally slows and vitality can decrease [31]. Compounding this are urban stresses such as soil compaction in schoolyards, mechanical damage, summer heat and drought, and pests (for example, horse chestnuts suffering leaf miner infestations) [32, 33]. As a result, only a small percentage of trees can be considered fully healthy and vigorously growing. This situation is typical for urban plantings in general [33]. The data highlight the need for enhanced maintenance measures: regular sanitary pruning, treatment of affected trees, watering during droughts, and soil amelioration. The 3% of trees in poor (dangerous) condition are of particular concern – they should either be rehabilitated with arboricultural techniques or removed and replaced with young, healthy specimens. Improving the proportion of trees in good condition will directly influence the effectiveness of the plantings in fulfilling their ecological and aesthetic functions.

Conclusions and prospects for further research. Out of 36 schools assessed, 33% fell into the "High" greening category (>55% green cover), 17% "Meet Standard" (45–55%), while the remaining 50% failed to meet the requirement: 22% were "Insufficient" (25–44%) and 28% "Critically Low" (<25%). The inventory recorded only

30 species of trees and shrubs (26 genera, 16 families) on the school grounds, indicating relatively low taxonomic diversity. Rosaceae (8 species) and Pinaceae (4 species) were the most represented families; most other families were represented by only one or two species. Such limited species richness can reduce the resilience of these plantings to pests and diminish their aesthetic value. These results highlight an urgent need for greening improvements in about 50% of the schools to meet the national standard of 45–50% green coverage. Enhancing tree planting and expanding green areas will improve the ecological performance of school grounds, aligning with sustainable urban development goals. In practical terms, the findings provide a baseline for local authorities and educators to prioritize greening interventions. Future research could include monitoring the impact of implemented greening measures, extending the analysis to other regions, and studying how different planting strategies affect microclimate and educational outcomes.

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