

THE ROLE OF CONIFEROUS PLANTS IN ENHANCING ADAPTABILITY, AESTHETIC AND RECREATION VALUES OF URBAN LANDSCAPES

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Abstract

Urban environments present unique climatic challenges, necessitating the use of coniferous plants to optimize the recreational bioclimate in large parks and public spaces. This study examines the adaptive capacities, year-round aesthetic value, and structural utility of gymnosperms within Poland's urban landscapes. By integrating extensive field inventories (2008-2025) with detailed evaluations of tree stand parameters, the research analyzes how species composition and canopy closure influence the phytoclimate of urban stand interiors. The findings indicate that strategically managed coniferous plantings can create luminous, loose stands that provide high recreational comfort, optimal lighting, and effective air ventilation. Additionally, such spatial structures support denser, more resilient undergrowth with increased tolerance to intensive recreational use and trampling. However, the vitality and aesthetic quality of urban gymnosperms are continually threatened by severe environmental stressors, including soil compaction, increasing salinization, and prolonged drought. To balance environmental landscape protection with intensive public use, provenance-aware species selection and the development of diverse, multi-layered stands are strongly recommended. These integrated strategies are essential for establishing self-regulating, sustainable green systems that enhance both long-term ecological resilience and daily leisure utility in modern cities.

Key words: canopy closure, environmental stress, gymnosperms, leisure spaces, plant provenance

Introduction

Gymnosperms represent a significant taxonomic group within the Polish flora, contributing substantially to both historic and contemporary landscape architecture. The ongoing process of urbanization introduces challenges such as air pollution, soil degradation, and increased frequency of extreme weather events. In this context, a thorough analysis of the botanical characteristics, aesthetic value, and structural applications of coniferous trees and shrubs in urban greenery is essential for the effective design of parks, gardens, and other green infrastructure [Konijnendijk et al., 2005].

Long-term assessments of park stands and street trees demonstrate that gymnosperm trees and shrubs provide unique year-round aesthetic value and play essential roles in shaping the urban recreational bioclimate [Nowak & Dwyer, 2007; Łukaszkiwicz, 2019]. However, increasing human impact and climate change complicate their suitability for heavily used public spaces. While these species are valued for morphological and physiological traits that, in theory, confer stress tolerance, traditional monocultures of gymnosperms exhibit significant adaptive limitations under rapidly changing climatic conditions. This raises concerns regarding their resilience and safety in public leisure areas [Allen et al., 2009; Dyderski et al., 2017]. In alignment with the conference theme of balancing landscape protection and public recreation, this paper critically evaluates the adaptive capacity, structural utility, and aesthetic values of gymnosperms under urban environmental stress, with emphasis on their role in optimizing public recreational spaces.

Material and methods

This study combines a systematic literature review with extensive field inventories to critically examine the botanical traits of gymnosperms and their current applications in urban greenery. Initially, a synthesis of information on the adaptive capacities of selected species and their utility in urban revitalization was compiled using international and national databases (Web of Science, Scopus). A meta-analysis of empirical studies on species resistance to drought, pollution, and salinity was conducted to identify knowledge gaps and select taxa for field investigation.

Field investigations were conducted between 2008 and 2025 across urban parks, gardens, avenues, and small leisure green spaces in Poland [Łukaszkiwicz, 2019; Fortuna-Antoszkiewicz, 2019]. Dendrometric measurements included tree height, trunk circumference at 1.3 m (DBH), and crown dimensions. Recreational utility was assessed by evaluating canopy closure, light permeability to the forest floor, and the resilience of undergrowth to recreational movement and trampling. Health and vitality assessments adhered to standardized protocols, including defoliation, dieback, and bark

damage. The habitat dataset included soil characteristics and anthropogenic indicators such as surface type, mechanical compaction, and available root substrate volume [Łukaszkiwicz et al., 2022].

Results

Shaping the Recreational Bioclimate and Stand Structure. Coniferous trees occupy a dominant position in Polish plant communities and possess distinct morphological traits that influence their role in the cultural landscape. In urban parks, the structure of coniferous tree stands directly affects the recreational bioclimate. Field analyses indicate that strategically managed species, such as *Pinus sylvestris* and *Larix decidua*, can be used to create luminous, loose stands. These spatial arrangements permit adequate sunlight penetration and air ventilation, thereby optimizing thermal comfort for park visitors. Additionally, lower canopy closure encourages the development of a denser, multi-layered undergrowth. Observations confirm that this herbaceous layer demonstrates significantly greater tolerance to mechanical damage, including intensive recreational trampling, compared to undergrowth in dense, unmanaged coniferous thickets.

Adaptive Traits and Vulnerability to Urban Stressors. Although gymnosperms possess anatomical and physiological adaptations to manage water stress, such as thick cuticles and small needle surfaces, their performance in urban environments is limited. Field inventories reveal that intensive urbanization adversely affects conifer health, frequently resulting in dieback and diminished aesthetic value [Gillner et al., 2014]. Major challenges to their maintenance in public spaces include mechanical soil compaction [Tracy et al., 2011], restricted rooting volumes (for example, tree pits within paved surfaces and root damage from earthworks) [Łukaszkiwicz et al., 2022], and chemical pollution, particularly salinization from de-icing agents.

Prolonged droughts in recent decades have led to increased mortality among native species such as *Picea abies*, which have been traditionally used in urban plantings [Allen et al., 2009; Dyderski et al., 2017]. While species such as *Pinus nigra* and introduced taxa like *Pseudotsuga menziesii* exhibit greater localized adaptation potential, their resistance is variable. The decline of these trees directly diminishes the visual quality of leisure spaces and compromises public safety through structural weakening, the accumulation of deadwood, and an increased risk of windthrow.

Discussion

The findings reveal a significant discrepancy between gymnosperms' theoretical drought tolerance and their actual survival in highly compacted, polluted urban soils. It is an oversimplification to claim that the anatomical traits of coniferous plants guarantee universal resistance in urban environments. Traits that promote stable growth in natural forest ecosystems may, in fact, increase vulnerability for trees planted along transportation corridors or in heavily trampled recreational areas [Gillner et al., 2014].

From a recreational standpoint, the inclusion of conifers in public spaces is highly advantageous. These species provide year-round greenery, enhance psychological well-being, reduce noise, and filter particulate matter (PM_{2.5}, PM₁₀) through their evergreen needles [Nowak & Dwyer, 2007; Wolf, 2017]. However, the effectiveness of these ecosystem services is strongly influenced by crown morphology and spatial arrangement. Dense, unthinned monocultures do not provide adequate shading or ventilation and restrict spatial readability, thereby limiting safe recreational access. In contrast, incorporating conifers into mixed-species plantings increases ecosystem resilience and stability, supports a wider range of ecological niches, and reduces the risk of large-scale dieback.

To effectively balance landscape protection with public use, urban planting design should avoid homogeneous conifer groupings. The adaptive capacity of conifers is significantly affected by their genetic provenance. Consequently, it is essential to prioritize planting stock from controlled, stress-tested sources and to match the vigor of specific taxa to the available rooting volume to ensure long-term biomechanical stability and recreational safety [Łukaszkiwicz et al., 2022].

Conclusion

The incorporation of gymnosperms in urban greenery remains highly relevant, especially for enhancing the aesthetic and climatic quality of public leisure spaces. However, successful integration necessitates a shift from perceiving these species solely as ornamental elements to recognizing their functional role within the urban bioclimate. To maximize ecological benefits and recreational utility, the following recommendations are proposed:

- integrate conifers into diverse, multi-layered mixed planting schemes rather than monocultures;
- form loose, luminous stands that support air ventilation and the growth of trampling-resistant undergrowth;

- select resilient taxa based on genetic provenance and documented tolerance to urban stressors (compaction, salinity, drought);
- provide adequate volumes of rooting soil and implement long-term monitoring of structural stability to ensure the safety of park users.

Implementing these strategies will foster self-regulating, sustainable green systems that effectively balance landscape protection with daily public recreation.

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Souhrn

Tento článek analyzuje úlohu jehličnatých rostlin při vytváření optimálního rekreačního bioklimatu v městských parcích, přičemž usiluje o rovnováhu mezi ochranou krajiny a intenzivním veřejným využíváním. Ačkoli strategicky spravované, řídké porosty jehličnanů poskytují vynikající tepelný komfort a podporují růst podrostu odolného proti pošlapání, jejich životaschopnost je vážně ohrožena městskými stresovými faktory, jako je zhutnění půdy, zasolení a sucho. Aby byla zajištěna dlouhodobá ekologická odolnost a bezpečnost pro rekreaci, studie důrazně doporučuje rozmanité, vícevrstvé smíšené výsadby a pečlivý výběr druhů na základě genetického původu.

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