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VÁROSI FÁK ALKALMASSÁGI VIZSGÁLATA ULÁNBÁTORBAN

Fafaj-választás a leghidegebb főváros számára – Narratív szakirodalmi áttekintés

URBAN TREE SUITABILITY IN ULAANBAATAR

Street Tree Selection for the Coldest Capital City – Narrative literature review

GANKHUYAG, ANUDARI | ÁGNES SALLAY

ABSZTAKT

Az utcai fák a városi zöldinfrastruktúra fontos elemei. Ökológiai előnyeik maximalizálása érdekében a tervezésnek figyelembe kell vennie az ökoszisztéma-szolgáltatásokat (ES) és -károsításokat (EDS), valamint az egyes fajok fenntartási igényeit. Ulánbátor, mint a leghidegebb főváros, amely gyors éghajlatváltozásnak van kitéve, egyedülálló kihívásokkal szembesül az utcai fák kiválasztása terén. Jelenleg a város utcai fáinak többsége egyöntetűen nyárfa. A fák kiválasztásának folyamata a nemzeti irányelveket követi, amelyben a lakosság véleményét alig veszik figyelembe. Az ulánbátori városi fák tényleges alkalmassága és a lakosság a kérdéssel kapcsolatos véleménye eddig még nem került kellőképpen feltárásra. Ez a tanulmány ezt a hiányosságot kívánja pótolni azáltal, hogy megvizsgálja a városban gyakran ültetett négy őshonos fafaj (Populus laurifolia, Ulmus pumila, Larix sibirica, Pinus sylvestris) jellemzőit, és feltárja a közvéleménynek ezekkel kapcsolatos véleményét. Narratív irodalomáttekintést végeztünk az egyes fajok jellemzőinek megértése érdekében, és feltáró kérdőívet (n = 55) töltettünk ki a lakosság véleményének megismerésére. Az NDVI-elemzés (2019-2024) kontextuális vegetációs változási adatokat szolgáltatott. Az eredmények azt mutatják, hogy bár az összes faj alkalmas a rendkívül hideg környezetre, stressztűrésük és ES/EDS-ellátásuk tekintetében jelentősen eltérnek egymástól. A kérdőív eredményei az örökzöld fajok iránti preferenciát és a széles levelű fajok iránti pozitív megítélést mutatták, annak ellenére, hogy az EDS-t negatívan értékelték. Kutatási eredményeink rávilágítanak arra, hogy mennyire fontos, milyen fafajokat ültetünk a közterületekre, és hogy a döntéseknél figyelembe kell venni a fafajok ökológiai teljesítményét és a lakosság preferenciáit.

Kulcsszavak: városi fák kiválasztása, rendkívül hideg éghajlat, városi erdőgazdálkodás, ökoszisztéma-szolgáltatások, ökoszisztéma-káros hatásai ⦿

ABSTRACT

Street trees are a crucial component of urban green infrastructure. To maximize their ecological benefits, planning should consider the ecosystem services (ES) and disservices (EDS), and maintenance requirements of each species. As the world's coldest capital city—but one undergoing rapid climate change—the city of Ulaanbaatar faces unique challenges in street tree selection. The current street tree population shows increasing homogenization, with the majority consisting of poplars. The tree selection process follows national guidelines, with limited inclusion of public opinion. The suitability of urban tree species in Ulaanbaatar, as well as public perceptions, remain underexplored. This study aims to address this gap by investigating the characteristics of four commonly planted native tree species (Populus laurifolia, Ulmus pumila, Larix sibirica, Pinus sylvestris) and exploring public perceptions of them. A narrative literature review was conducted to examine the species traits, and an exploratory questionnaire (n = 55) was used to assess public perception. NDVI analysis (2019–2024) provided contextual data on vegetation change. Findings indicate that while all species are suitable for environments of extreme cold, they differ significantly in stress tolerance and ES/EDS provision. Questionnaire results revealed a preference for evergreen species, and a generally positive perception of broad-leaved species despite perceived disservices. These insights highlight the importance of aligning planting decisions with species-specific ecological performance and incorporating public preferences into planning processes.

Keywords: urban tree selection, extreme cold climate, urban forestry, ecosystem services, ecosystem disservices

1. INTRODUCTION

Street trees often provide the most immediate and accessible ecosystem services (ES), especially in the cities that have limited urban parks (Sharmin et al., 2026). Choosing a suitable street tree species is crucial, given that they take years to reach a size that enables them to provide substantial ES (Esperon-Rodriguez et al., 2022), and each species provides different benefits (Tuffaha & Sallay, 2025). Street trees experience different growth conditions than those in natural environments, and their growth is limited by factors such as pruning and space limitations (Muscas et al., 2023; Tóth et al., 2025). Therefore, to choose a suitable tree for a city, individual tree needs, tolerance to particularly stressful environmental conditions, and the needs and interests of local communities need to be considered (Poulton Kamakura et al., 2025). Current tree selection for Ulaanbaatar primarily follows guidance from the Construction Norms and Rules of Mongolia, which consider aesthetic value, soil and climate, tolerance to air pollution, and preferences for sunlight or shade. Other important requirements, such as cold hardiness, maintenance needs, and allergenicity, are not mentioned in the current normative framework. Public perceptions and preferences regarding urban trees in Ulaanbaatar are not incorporated into the tree selection guidelines and remain unexplored academically.

1.1. Background

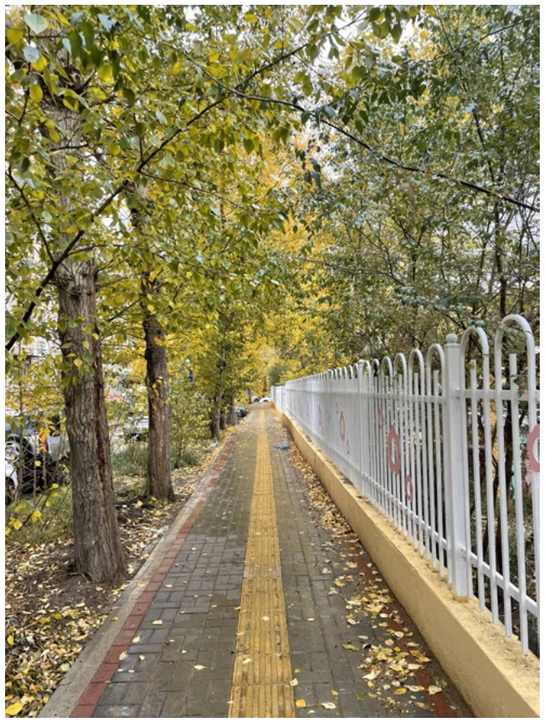
Ulaanbaatar is the capital and most populous city of Mongolia. The climate of the city is characterized by extremely cold winters (De Grandpré et al., 2011), low precipitation (Nandintsetseg & Shinoda, 2011), and increasing warming trends (Nandintsetseg et al., 2021). The urban environment of Ulaanbaatar is subject to pollution stressors, including heavy metal contamination of the soil (Batjargal et al., 2010; Battsengel et al., 2020; Oyunbat et al., 2021) and seasonal air pollution (Amarsaikhan et al., 2014; Guttikunda et al., 2013).

1.2. Urban street trees

After the democratic revolution, urban green spaces in Ulaanbaatar experienced significant degradation due to financial constraints and legal changes (Bayantur & Amarsaikhan, 2006). Most of the city's street trees and urban parks were established at the beginning of the 20th century, and Soviet architects made the tree selections. Currently, street tree composition exhibits a trend toward homogenization, with poplars dominating the inventory, as approximately 75% of specimens consist of *Populus laurifolia* (Kasimov et al., 2011) (Figure 1). This homogenization increases pest vulnerability and reduces long-term stability.

1.3. Objective

Given the current species homogenization, lack of public consultation on tree selection, rapid urbanization, and changing climate, it is necessary to assess the suitability of street trees in Ulaanbaatar and explore diversification opportunities. This study aims to achieve this through a narrative literature review and an exploratory



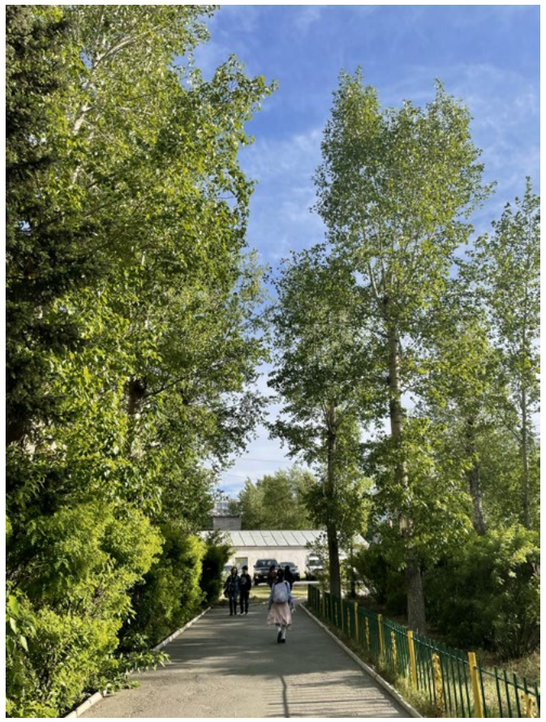


Figure 1: Poplar trees in Ulaanbaatar
PHOTO TAKEN BY THE AUTHOR IN 2022

questionnaire. Additionally, remote sensing analysis of vegetation change provides contextual information on the spatial distribution of urban vegetation.

2. MATERIALS AND METHODS

Previous tree species studies conducted in Ulaanbaatar city have predominantly concentrated on native species, primarily on conifers including *Larix sibirica* and *Pinus sylvestris,* and broad-leaved deciduous trees such as *Populus laurifolia* and *Ulmus pumila.* In urban areas of Ulaanbaatar, *P. laurifolia* and *U. pumila* have long been planted due to their high adaptability to poor environments (Byambasuren et al., 2024), whereas *L. sibirica* and *P. sylvestris* are the dominant tree species in the wild forest of Mongolia (Batsaikhan et al., 2024). These four commonly planted native species were selected for this research. The methodology of the study consists of three main parts, utilizing a mixed-methods approach. First, a narrative literature review of diverse sources was conducted to synthesize existing knowledge on ED-EDS trade-offs and species-specific characteristics. Secondly, a questionnaire containing three parts was created and distributed to explore the perception of street trees and their associated benefits, as well as concerns about them. The questionnaire aimed to identify tendencies in preferences and to explore perceptions of urban trees, rather than to make city-wide generalizations. Lastly, as a contextual addition to the vegetation of Ulaanbaatar, NDVI analysis was conducted to assess the city's existing tree cover and changes over the past five years. Tree cover in Ulaanbaatar is not distributed evenly across the city, and an examination of existing canopy cover is necessary to reveal this unequal distribution.

2.1. Literature review

A narrative literature review on cold tolerance, maintenance, and ES and EDS was conducted on Scopus and Google Scholar databases during November and December of 2025. Studies on physiology, ecology, and urban contexts were included. Literature collection was conducted with the following keywords – *urban tree, cold tolerance tree, street tree ecosystem service/disservice,* and *Populus laurifolia, Ulmus pumila, Larix sibirica, Pinus sylvestris.* Articles were screened by title and abstract relevance, prioritizing urban, cold, semi-arid contexts, and both urban and natural environments were considered. Findings were synthesized through a thematic analysis focused on ES/EDS trade-offs, urban stress tolerance, and unique characteristics. The Ogren Plant Allergy Scale, a common tool for evaluating the allergenicity of plant species (Cariñanos & Casares-Porcel, 2011; Nowak & Ogren, 2021), was used to examine the allergenicity of the tree species chosen for this study.

2.2. Resident Perception Exploratory Questionnaire

Although street trees directly influence the everyday lives of urban residents, the perception and preferences of residents of Ulaanbaatar have received limited scholarly attention. An exploratory questionnaire (Appendix A) was designed to assess public perceptions of street trees. Results of the survey were used for a qualitative comparison with the ES and EDS of species based on the literature review.

The questionnaire has three sections: (i) demographic information, (ii) general street greenery of Ulaanbaatar, and (iii) specific tree ES and EDS preferences, as well as perception of the suitability of species. The introduction of the survey explained the anonymous and voluntary participation, and provided a short description of the aim. Section (ii) questions used a Likert scale, ranging from 1 (least agree) to 5 (most agree). Pictures of each tree species and descriptions were included. The survey was created in Mongolian on Google Forms and distributed online via social media platforms and professional networks, employing snowball sampling. A three-person pretest was conducted to ensure clarity.

Survey responses were downloaded and analyzed using Microsoft Excel. Section (i) provided data on the demographic composition of the respondents. The majority groups among survey takers were revealed, and potential bias was assumed. For (ii) questions, responses were summarized to identify the frequency and percentage distribution of each response category. The results of this section were interpreted based on dominant response trends. Section (iii) questions allowed multiple answers, and results were grouped and organized on Excel sheets. R Studio was used for visualizing response distribution across ES and EDS categories. Each ES and EDS was compared with the other in terms of perceived importance. A question regarding the perception of changes in the vegetation of Ulaanbaatar enabled the comparison of the results with the actual situation.

2.3. Remote sensing – Vegetation in the Ulaanbaatar context

To understand the need to investigate the suitability of urban trees in Ulaanbaatar, an assessment of the current state of urban vegetation was necessary. Previous spatial analyses of Ulaanbaatar have focused on urban sprawl and structural changes (Barbary & Forster, 2017; Batsuuri et al., 2020; Bayantur & Amarsaikhan, 2006; Purevtseren et al., 2019), land use (Boldbaatar et al., 2024; Damdinsuren et al., 2023), and urban green spaces (Altangerel & Jargaldalai, 2019). However, the availability of city-wide analyses of vegetation remains limited. Results of this remote sensing analysis focused on a) existing urban vegetation in Ulaanbaatar, and b) changes it has undergone in the past five years. Vegetation of Ulaanbaatar was calculated using Normalized Difference Vegetation Index (NDVI) layers from Sentinel-2 images from the years 2019 and 2024, with a resolution of 10m. Images are selected from the peak growth season in Mongolia (2019.08.03 and 2024.08.26) with cloud cover less than 20%. Since the reason for this analysis was to provide context about the city's vegetation while observing changes, two images from peak growth season with minimal cloud cover were sufficient.

NDVI was calculated with the standard formula (Ozyavuz et al., 2015):

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

Where the near-infrared (NIR) corresponds to Band 8 and red bands to Band 4 of Sentinel-2 images (Pałaś & Zawadzki, 2020), NDVI values between 0.2 and 0.3 represent shrub and grassland, and high values (0.6 to 0.8) indicate temperate rainforests (Gandhi et al., 2015).
A previous study revealed that the Ulaanbaatar area falls within the "sparse to dense vegetation" category in NDVI pixel-value classification, with mean pixel values ranging from 0.37 to 0.60 (Yondonrentsen et al., 2023). Therefore, to analyze the tree-dominated vegetation, binary masks with an NDVI threshold of >=0.5 were created on each year layer. Pixels meeting the threshold were assigned a value of 1 (tree cover); others were assigned a value of 0.

The tree-dominated area was calculated using the zonal statistics tool in QGIS 3.34.11, with the built-up area of Ulaanbaatar used as the zone layer and binary tree masks as the input raster. For each year's layers, the pixel sums within the boundary were calculated, and tree-covered pixels were estimated. With a resolution of 10x10m,

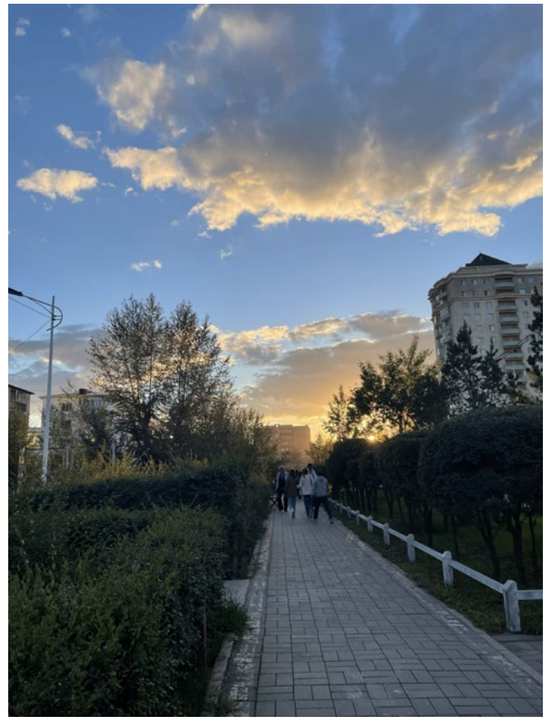
◂◂**Figure 2:** Poplar trees shedding cotton fluff in June 2025, Ulaanbaatar
PHOTO BY THE AUTHOR

Figure 3: Ulmus pumila in Ulaanbaatar streets in June and August
PHOTO BY THE AUTHOR









each pixel represents a 100 m² area of land (Skachkova, 2025). With these numbers, the tree-covered area was calculated in terms of pixels and land area.

3. RESULTS

3.1. Literature review

The following review analyzes the physiology and distinctive features of each species. The literature was synthesized into ES/EDS trade-offs, stress tolerance, and unique characteristics.

3.1.1. Populus laurifolia

Populus is a widely distributed genus in the Northern Hemisphere, and its economic and ecological importance is well known. *P. laurifolia* reproduces through seed and pollen dispersal (Figure 2), and also propagates sexually via roots and root suckers in harsh environments, producing large and long-lived clonal units (Wiehle et al., 2016). Poplar tree seeds are dispersed from May to mid-June, and only female trees produce this visible cotton fluffs. However, the poplar cotton fluff that protects the seeds is not allergenic; rather, it serves as a trap for other allergenic pollens (Hu et al., 2008). By the allergenicity score of OPALS, poplar cotton fluff seeds rate 1, whereas male-produced pollens are more allergenic, with a rating of 9.

Poplars are commonly used in urban environments due to their rapid growth (Kohán, 2003). The majority of street trees in Ulaanbaatar are poplars. Fast growth enables rapid greening of areas and the creation of tree canopy cover, contributing to ecosystem benefits such as shade provision, air quality improvement, and enhancements to the visual aesthetic of urban space almost immediately (Łukaszkiewicz et al., 2024; Zalesny et al., 2019). They are suitable street trees in highly polluted cities, as they act as the best bioconcentrators, and are capable of functioning even in a harsh urban environment (Kasimov et al., 2011). *P. laurifolia* adjusts its morphology to conserve resources when the site is less fertile (Byambasuren et al., 2024). It is cold-hardy, with a tolerance down to –70 °C (Sakai, 1979). At the same time, radial growth accelerates with rising temperatures (Liang et al., 2024).

3.1.2. Ulmus pumila

U. pumila is a drought-resistant tree, native to southern Mongolia, China, Korea, and Russia, with a capacity to grow in an environment with average annual precipitation levels ranging from less than 100 mm to over 1300 mm (Avirmed et al., 2022 (Mu & Ding, 2022)). With its deep-reaching roots and the ability to adjust leaf osmotic potential, *U. pumila* can avoid severe drought damage in most summers and grow in the deserts of southern Mongolia (Dulamsuren, Hauck, Nyambayar, et al., 2009). This species readily adjusts to site conditions through its physiological processes and is well adapted to urban environments (Byambasuren et al., 2024). *U. pumila* can tolerate sunny, dry, warm conditions, and primarily grows in the understory layer in urban landscapes (Sjöman et al., 2012). It can grow for a long period, notably growing over 100 years in some Chinese cities (Yang et al., 2022). In the streets of Ulaanbaatar, *U. pumila* is planted as an understory layer, and is typically well-trimmed in the city center (Figure 3).

This position of plantation is useful for reducing urban noise pollution, providing a positive soundscape through landscape design (Jo & Jeon, 2020). The porous and structured bark of *U. pumila* helps accumulate atmospheric dust and enhances air quality in the urban environment (Mousavi et al., 2026). While *U. pumila* is wind-pollinated, and allergenic (Hu et al., 2008), with pollen reduction measures such as direct pruning, allergenicity can be prevented.

3.1.3. Larix sibirica

L. sibirica and *P. sylvestris* are native to boreal forests (Rupyshev et al., 2024), and amongst the most common tree species used in urban streets in arctic cities due to their capacity to survive in harsh climates and short growing periods (McBride & Douhovnikoff, 2012). Natural forests in Mongolia's ecotone are predominantly dominated by Siberian larch *(L. sibirica),* and they are found to have low water shoot potential. Young larch trees are more susceptible to drought than the mature trees (Dulamsuren et al., 2008), making them unsuitable for arid environments. *L. sibirica* frequently shows severe drought stress compared to *P. sylvestris,* which implies that global warming would have a greater impact on them (Dulamsuren, Hauck, Bader, et al., 2009). In the CO_2 adsorption study conducted in Ulaanbaatar by Bayasgalankhuu et al. (2022), larch trees exhibited the highest carbon sequestration flux among the studied species, including *P. laurifolia* and *P. sylvestris.* Since the needles of the larch tree are more sensitive to pollution, they can be used as a bioindicator, but this also makes them vulnerable to a polluted environment (Kasimov et al., 2011). *L. sibirica* is typically planted in shaded areas of Ulaanbaatar, primarily in the city center (Figure 4). This