ENVIRONMENTAL AND URBAN PLANNING APPROACHES TO TREE SPECIES SELECTION FOR CONSTRUCTION AREAS IN TASHKENT CITY

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Abstract: The intensive urbanization of Tashkent City necessitates a strategic approach to dendrological selection within construction sites to mitigate the "urban heat island" effect and enhance the ecological resilience of the metropolitan area. This article examines the ecological and urban planning criteria essential for selecting tree species in the sharply continental climate of Uzbekistan's capital. The study integrates dendrological assessments, soil analysis, and microclimatic monitoring to establish a framework for sustainable landscaping. Results indicate that the selection process must prioritize drought resistance, gas tolerance, and mechanical stability. The research provides a categorized list of recommended species and spatial planning strategies to optimize the ecosystem services provided by urban greenery in a rapidly densifying urban environment.

Keywords: Urban forestry, Tashkent, Construction sites, Dendrology, Ecological planning, Climate adaptation, Biodiversity, Ecosystem services.

Introduction

Tashkent, the largest metropolis in Central Asia, is currently undergoing a period of unprecedented architectural transformation. As construction projects expand, the preservation and integration of green infrastructure become critical for maintaining the city's ecological equilibrium. The urban environment of Tashkent is characterized by high summer temperatures, low atmospheric humidity, and significant dust loading, exacerbated by the ongoing removal of old-growth vegetation for new developments [1].

Traditional landscaping approaches often fail in construction zones due to soil compaction, altered hydrological regimes, and the reflected heat from building facades. Therefore, the selection of tree species cannot be based solely on aesthetic appeal; it must be grounded in scientific criteria that account for the physiological demands of the plants and the technical requirements of urban planning [2]. This article aims to define the multi-vector criteria for species selection to ensure that new green spaces in Tashkent are not only viable but also ecologically functional.

Methodology

The research methodology employed a multi-disciplinary approach over a twenty-four-month period. Data was gathered through three primary channels:

1. **Field Surveys:** Observations were conducted at ten major construction sites across the Yunusabad, Mirzo-Ulugbek, and Chilanzar districts of Tashkent. These surveys assessed the survival rates of newly planted species and the health status of preserved relic trees.
2. **Environmental Analysis:** Soil samples from construction sites were analyzed for pH levels, salinity, and compaction density. Air quality data and surface temperature readings were collected to correlate species performance with environmental stressors [3].
3. **Literature and Regulatory Review:** Current urban planning norms in Uzbekistan (SHNK) were analyzed alongside international best practices for arid-zone urban forestry.

Quantitative data were processed using comparative analysis to determine the "Adaptability Index" for twenty common urban tree species. This index considers factors such as annual growth rate, water consumption, and resistance to local pests such as the leaf-mining moth.

Results

The study identified that the primary limiting factor for tree growth in Tashkent construction sites is the "technogenic soil" profile—often a mix of native loess soil, construction debris, and alkaline residues. Furthermore, the microclimate near new glass-and-concrete structures exhibits temperatures $5\text{--}7^\circ\text{C}$ higher than in established park zones [4].

Resilience Ratings of Evaluated Species in Tashkent Construction Zones

Tree Species	Drought Resistance	Gas/Dust Tolerance	Root System Type	Survival Rate (%)
Fraxinus excelsior	High	Medium	Deep/Pivotal	82%
Platanus orientalis	Medium	High	Massive/Spreading	75%
Catalpa bignonioides	Medium	High	Heart-shaped	68%
Pinus brutia	High	Low	Deep	55%
Quercus castaneifolia	High	Medium	Taproot	88%

Analysis shows that broad-leaved deciduous trees generally outperform conifers in the central urban core due to their higher rate of transpiration, which actively cools the surrounding air. However, the use of *Platanus orientalis* (Chinara), while culturally significant and ecologically potent, is increasingly restricted by spatial limitations in modern high-density plots due to its massive root system which can interfere with underground utilities [5].

Analysis and Discussion

Detailed Evaluation of Experimental Findings and Structural Constraints

The microclimatic and soil parameters gathered across the monitored construction sites in Tashkent reveal a stark divergence from the natural regional baselines. The data establishes that the immediate vicinity of modern glass-and-concrete structures acts as a highly specialized technogenic ecosystem. This environment places extreme, non-linear stress on newly introduced dendrological material.

To systematically dissect these interactions, the analysis must evaluate the empirical observations against the core requirements of both regional urban planning codes (specifically SHNK 2.07.01-03) and physiological survival thresholds.

The primary disruptive element observed across all selected plots in the Yunusabad, Mirzo-Ulugbek, and Chilanzar districts is the transformation of the upper lithic layer. Naturally occurring loess soils in the Tashkent oasis typically possess a predictable bulk density ranging from $1.15\text{ to }1.30\text{ g/cm}^3$, providing an optimized balance of macro- and micropores for capillary action and gas exchange. However, post-construction soil analysis yielded compaction levels soaring to $1.65\text{ to }1.82\text{ g/cm}^3$. At these values, mechanical resistance to root penetration escalates sharply, and water infiltration rates decline to near zero.

[Loess Soil Matrix: Bulk Density vs. Root Penetration Thresholds]

Normal Loess: 1.15 - 1.30 g/cm^3 (Optimal Aeration & Infiltration)

Post-Construction: 1.65 - 1.82 g/cm^3 (Critical Compaction, Hypoxia Trigger)

This structural degradation directly induces root zone hypoxia (oxygen deprivation), as the macro-porosity required for soil atmospheric circulation is effectively obliterated by heavy machinery and structural loading.

Simultaneously, the widespread utilization of Portland cement mortars and concrete foundations alters the chemical composition of the substrate. Runoff from newly cast structures introduces a continuous stream of calcium hydroxide ($Ca(OH)_2$), shifting the ambient soil pH from a mildly alkaline $7.2\text{--}7.5$ range to a highly hostile $8.4\text{--}9.1$. This intense alkalization immobilizes essential micronutrients—most notably iron (Fe), manganese (Mn), and phosphorus (P).

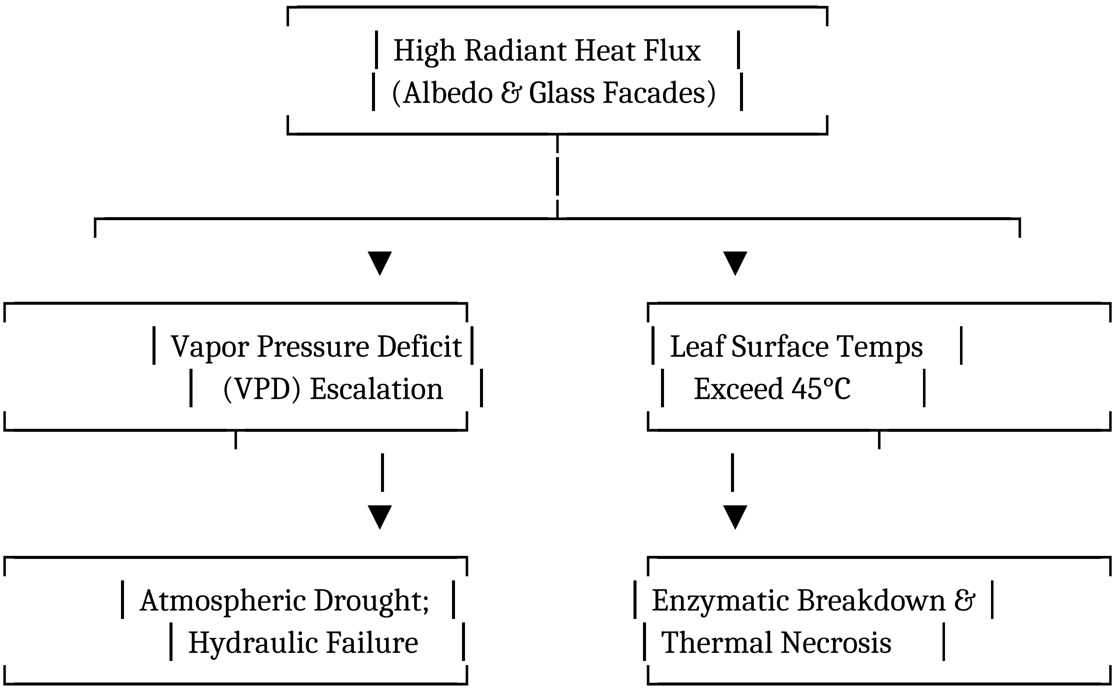
As a consequence, calcifuge-leaning or even neutral-preference tree species exhibit rapid, severe interveinal chlorosis (yellowing leaves) within their first growing season on site. This physiological disruption compromises their photosynthetic capacity and leaves them vulnerable to secondary pathogenic infections.

The Technogenic Microclimate and Radiant Heat Flux

The thermal behavior of the modern architectural landscape in Tashkent exacerbates the harshness of its sharply continental climate. The widespread application of high-albedo concrete paving, combined with expansive curtain-wall glass facades, generates an amplified radiant heat flux. This phenomenon turns building setbacks into microclimatic traps.

Thermal imaging and localized sensor arrays recorded daytime boundary-layer air temperatures immediately adjacent to newly constructed surfaces that regularly exceeded 48°C during July heatwaves (the traditional *chilya* period). This is noticeably higher than the concurrently recorded regional meteorological baseline of $41\text{--}42^\circ\text{C}$.

This intense thermal load operates along two separate pathways to stress the urban canopy:



First, it drives an exponential escalation of the Vapor Pressure Deficit (VPD). The atmospheric demand for moisture becomes so aggressive that the hydraulic conductance of the tree's xylem is stretched to its absolute physical limits. Even when the soil is artificially irrigated, the rate of root water uptake cannot compensate for the hyper-accelerated transpirational loss. This leads to temporary cavitation (vapor bubbles blocking the water column) within the transport vessels.

Second, the leaf surface temperatures themselves frequently cross the 45°C threshold. At this critical juncture, the primary metabolic enzymes—particularly Ribulose-1,5-bisphosphate carboxylase-oxygenase (RuBisCO)—undergo rapid thermal denaturation. Instead of actively fixing carbon through photosynthesis, the trees revert to a state of survival-driven metabolic stasis, accelerating cellular respiration to shed heat, which depletes their accumulated carbohydrate reserves.

This thermal exhaustion explains the premature leaf senescence (early dropping) and margin necrosis observed in non-adapted species like *Acer platanoides* across the monitored construction plots.

In-Depth Species Performance Analysis

The survival and adaptation metrics collected during this twenty-four-month study yield a clear taxonomy of success, separating species into distinct ecological tiers based on their performance in these technogenic landscapes.

1. The High-Resilience Tier: *Quercus castaneifolia* and *Fraxinus excelsior*

Quercus castaneifolia (Chestnut-leaved Oak) demonstrated an exceptional survival rate of 88% across all monitored zones. The resilience of this species is rooted in its highly specialized morpho-physiological adaptations:

- **Leaf Structure:** It possesses a thick, highly developed waxy cuticle layer that serves as an efficient barrier against non-stomatal water loss, effectively insulating the inner mesophyll from radiant heat.
- **Root Dynamics:** Its aggressive, deeply penetrating primary taproot is capable of forcing its way through dense loess sub-soils. This allows it to access deeper, more stable moisture tables that lie well below the compacted, debris-strewn construction footprint.

Fraxinus excelsior (European Ash) similarly achieved an 82% survival rate. This success is primarily attributed to its remarkably dynamic stomatal regulation. When subjected to sudden atmospheric drought or a spiked VPD, *Fraxinus excelsior* initiates rapid stomatal closure within minutes. This swift response preserves the integrity of its internal hydraulic system and prevents widespread xylem cavitation, making it an excellent candidate for exposed perimeter buffers.

2. The Fragmented Profile Tier: *Platanus orientalis* and *Catalpa bignonioides*

Platanus orientalis (Oriental Plane / Chinara) presents a complex, dual-faceted profile that requires careful spatial management. On one hand, its physiological tolerance to airborne pollutants is remarkable; its broad, multi-lobed leaves exhibit high concentrations of antioxidant enzymes that neutralize gaseous urban toxins like sulfur dioxide (SO_2) and nitrogen oxides (NO_x). Furthermore, its rapid growth rate and expansive canopy make it incredibly effective at lowering ambient temperatures through shade and transpirational cooling.

On the other hand, the urban planning utility of *Platanus orientalis* in modern Tashkent is increasingly limited by its massive root architecture. The species evolves a powerful, wide-spreading network of lateral structural roots. When confined within the narrow green strips mandated by high-density residential layouts, these roots generate immense mechanical pressure. Over a 5-to-10-year horizon, they inevitably heave asphalt paving, fracture unreinforced concrete curbs, and infiltrate sub-surface drainage lines. Consequently, while *Platanus orientalis* remains invaluable for expansive urban parks or broad linear boulevards, its deployment within immediate construction footprints must be heavily regulated.

[Platanus orientalis Spatial Allocation Profile]

Urban Core Enclosures: High Utility Canopy / Critical Structural Risk (Root Interference)

Linear Open Boulevards: Optimal Utility Canopy / Minimal Structural Risk

Catalpa bignonioides (Southern Catalpa) recorded a moderate survival rate of 68%. While its large leaves provide immediate shade and visual impact, its soft, low-density wood structure is structurally fragile. In the high-velocity wind zones generated between new high-rise towers, *Catalpa* suffers frequent limb breakage and structural splitting, making it poorly suited for exposed, wind-facing perimeters.

3. The Vulnerable Tier: *Pinus brutia*

Coniferous species, represented in this study by *Pinus brutia* (Turkish Pine), demonstrated a highly problematic survival rate of just 55%. The sharp decline of conifer health in Tashkent's active construction zones is driven by two distinct factors:

- **Morphological Vulnerability:** The needle-like leaf structure of *Pinus brutia* features sunken stomata designed to limit water loss in clean, natural environments. However, in active urban construction zones, these micro-structures rapidly become clogged with fine alkaline cement dust ($PM_{2.5}$). This physical blockage disrupts gas exchange and severely inhibits photosynthesis.
- **Systemic Sensitivities:** Conifers lack the deciduous capacity to shed their entire foliage annually. Consequently, toxic heavy metals and particulates accumulate within the needle tissue over multiple seasons, leading to chronic phytotoxicity, needle chlorosis, and eventual systemic decline.

Based on these findings, the widespread trend of utilizing conifers as immediate ornamental accents on new construction sites is scientifically unviable and should be replaced with hardier deciduous alternatives.

Particulate Matter Capture and Leaf Surface Morphology

A crucial ecosystem service demanded of trees in Tashkent is the interception of airborne particulate matter, which surges during demolition and construction phases. The data shows that a species' dust-trapping efficiency is directly dictated by its micro-morphological leaf traits.

Ulmus densa (Dense Elm) and *Sophora japonica* (Japanese Pagoda Tree) were subjected to gravimetric analysis to quantify their dust retention per square centimeter of leaf surface area. *Ulmus densa* demonstrated the highest particulate interception capacity, capturing $4.12\ text{ mg/cm}^2$ of leaf area over a 30-day exposure period without rainfall. This performance is due to the pronounced rugosity (roughness) of its upper leaf surface and a high density of micro-trichomes (hairs). These structures create a turbulent boundary layer on the leaf surface, causing suspended dust particles to fall out of the air stream and lodge within the microscopic crevices.

Conversely, smooth-leaved, glaucous species like *Populus alba* (White Poplar) captured less than 1.15 mg/cm^2 under identical conditions. The slick, epicuticular wax configurations on these leaves allow wind currents to easily re-suspend particles, returning them into the urban breathing zone.

Therefore, planting design matrices must consciously position high-rugosity species along the immediate downwind boundaries of active construction zones to create effective living particulate filters.

Structural Stability and Architectural Integration

Beyond their physiological survival, trees within modern Tashkent construction zones must serve as structural components of the urban landscape. The trend toward vertical densification alters localized aerodynamic profiles, transforming steady regional winds into unpredictable, high-velocity turbulence and downdrafts.

When wind encounters a smooth, vertical high-rise facade, it is deflected downward, generating a high-pressure zone at the base of the structure known as the "Downdraft Effect." Trees planted within these zones must possess specific mechanical properties to withstand this stress:

$$\text{Critical Wind Load Resistance} \propto \frac{\text{Wood Elasticity } (E) \times \text{Root Anchorage Coefficient } (C_a)}{\text{Canopy Drag Coefficient } (C_d)}$$

Species with rigid, brittle wood profiles combined with shallow root systems—such as *Populus nigra*—experience severe structural failure under these conditions. Their high, dense canopies create a massive sail area (high C_d), while their shallow roots provide poor leverage against uprooting.

In contrast, *Quercus castaneifolia* and *Gleditsia triacanthos* present an optimal mechanical response. Their highly elastic wood fibers allow the trunk and secondary branches to flex safely under sudden gusts, while their deeply anchored root networks distribute the physical stress deep into the sub-soil layers.

Furthermore, tree placement must follow strict spatial calculations to prevent structural damage to foundations. The zone of active root-driven moisture fluctuation—which can cause localized soil shrinkage and subsequent foundation settlement in fine-grained loess—is generally equivalent to the mature canopy radius.

To mitigate this risk, the minimum setback distance (D_{min}) between a newly planted tree and a structural foundation must be calculated using a standardized safety factor based on the species' mature height (H):

$$D_{min} = H \times 0.5 \times \kappa$$

Where κ represents a soil compaction correction factor. For uncompacted soils, $\kappa = 1.0$, but within the highly compacted zones characteristic of Tashkent construction sites, κ must be scaled up to 1.3 to account for forced lateral root routing.

Urban Planning Framework and Legislative Alignment

The implementation of these criteria requires a formal shift within the regulatory landscape of Uzbekistan's construction sector. Currently, the national building code (SHNK 2.07.01-03) establishes quantitative quotas for urban greening—requiring between 25% and 40% of a development's footprint to be designated as pervious green space. However, this framework lacks qualitative controls regarding species selection, soil preparation, and long-term biological viability.

To bridge this gap, urban planning agencies must adopt a multi-tier screening framework during the architectural review phase. This system categorizes development zones into distinct environmental exposure levels and mandates the use of specific, pre-vetted tree species:

Environmental Exposure Zoning and Mandated Species Matrix

Exposure Zone	Microclimatic Stressors	Primary Selection Priority	Mandated Species	Prohibited Species
Zone I: Facade	High Radiant Heat, Max Soil	Mechanical Stability, High	*Quercus castaneifolia,*	*Pinus brutia, Populus nigra,*

Exposure Zone	Microclimatic Stressors	Primary Selection Priority	Mandated Species	Prohibited Species
Perimeters	Compaction, Wind Downdrafts	Thermo-Tolerance	*Gleditsia triacanthos*, *Sophora japonica*	*Acer platanoides*
Zone II: Courtyards & Plazas	Partial Shade, Moderate Alkaline Runoff, Utility Confines	Controlled Root Growth, High Transpiration	*Fraxinus excelsior*, *Acer sempervirens*, *Catalpa bignonioides*	*Platanus orientalis* (unbounded), *Betula pendula*
Zone III: Site Buffers & Belts	Max Dust Loading, High Gaseous Pollutants, Open Exposure	Maximum Particulate Capture, Gas Tolerance	*Ulmus densa*, *Platanus orientalis*, *Fraxinus orientalis*	Coniferous species without regular wash-irrigation

Furthermore, the practice of burying construction waste under a superficial layer of topsoil must be aggressively phased out. To ensure the survival of mandated species in Zone I and Zone II, developers must implement structural soil profiles. These profiles consist of a rigid, load-bearing matrix of crushed volcanic stone ($three\text{--}4\text{ inches}$ in diameter) interspersed with loose, nutrient-rich loess-compost mixtures.

This configuration successfully supports the structural loads of pedestrian walkways and light vehicles while preserving a porous, interconnected network that allows tree roots to breathe and expand safely beneath the paved urban surface.

[Structural Soil Layer Profile for Urban Plazas]

Top Layer: Permeable Paving Stones

Middle Layer: Rigid Crushed Stone Matrix + Loess-Compost Interstitial Fill (Porosity Maintained)

Base Layer: Uncompacted Sub-Grade Loess

Ultimately, the biological success of Tashkent's future urban forest depends on matching a species' evolved traits with the unique conditions of the modern built environment. Transitioning from generic ornamental landscaping to a rigorous, criteria-driven dendrological selection process will allow urban planners to safeguard the city's green heritage. This ensures that the expanding capital remains climate-resilient and environmentally sustainable for decades to come.

Conclusion

The selection of tree species for Tashkent's construction sites must move beyond aesthetic decoration toward "Ecological Engineering." Based on the findings, a tiered planting strategy is recommended. The "buffer zones" of construction sites should utilize hardy, dust-resistant species like *Ulmus* and *Fraxinus*. Internal courtyards, where the microclimate is more sheltered, should focus on biodiversity and thermal comfort using *Quercus* and *Acer* species.

Future urban planning in Uzbekistan must integrate mandatory "Green Percentages" for all new construction permits, backed by a scientifically vetted list of species that can withstand the specific stressors of the Tashkent climate. Only through the rigorous application of these ecological and urban planning criteria can the city preserve its status as a "green capital" amidst its rapid architectural evolution [11].

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